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**THE
NEW MANAGEMENT**

THE NEW MANAGEMENT

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TO
THE SERVICE OF ALL WORKERS
IN INDUSTRY OF WHATEVER RANK
OR OCCUPATION

May their labours ever grow easier,
pleasanter, and more useful, and their
material rewards increase faster than
their needs.

PREFACES

MANY books have been written on different branches or functions of management. There have been books on costing and the use of statistics, on progress planning, on systems for evaluating and paying for work, on selling and sales organising and management, on advertising and on publicity. Many of them are good books, written by masters of their subjects, but,—and there are several “buts.” For example, a good proportion of them come to us from other countries, where conditions are so different that although it is possible to learn from them, it may be dangerous to copy the methods advocated and apply them to British conditions. Some of them are too restricted in their subject-matter to be generally applicable. Others do not make sufficiently clear the fundamental principles to enable a manager to apply them to his own particular case, and he is therefore left either to copy the methods described, or to leave them alone, and usually the latter course is the safer.

In this book we have endeavoured to provide a treatise on management as a whole, for managers and potential managers. Executives *must* know the principles of each department of the subject, although they need not necessarily be specialists in any. We have tried to make clear, so far as a general and abstract treatment will permit, what the principles of management are, their connections and reactions upon one another, and their relative importance; and to give such positive and negative advice on their application as is possible without tempting the reader to apply them in circumstances that may be unsuitable.

So far as we know, no such book has yet been written or published; and we offer this volume in the hope that it may fill a need, and help readers to a more comprehensive understanding of the art of management, and a more satisfying use of the specialised literature available. Each incident and

example used for purposes of clarification and illustration is taken from the personal experience of one or other of us, gathered in Great Britain, in the United States of America, and in Germany. As regards the Bibliography, we thought it better that it should be prepared by one whose knowledge of the literature is more complete than ours. Accordingly, we requested the help of Mr. G. E. Milward of The Management Library, and are grateful to him both for the Bibliography itself, and for the form he has given to it.

We do not profess to embody original thought in this book, but we do endeavour to present well-known facts and practically proven experience in correct perspective. Still less do we pretend to expound any new methods or systems, or offer general solutions for all cases of specific problems; on the contrary, we show that such attempts, so often made, must lead to failure.

Why, then, is the book entitled *The New Management*? Our answer is: for the reason that it is written in the light of the new spirit that has appeared in industry during the present century: the spirit that has grown and spread so beneficently, sweetening the relations between all those engaged in industry to the general good; the spirit of friendship and willing co-operation between owners, management and workers, with the State holding a watching brief, and humanity as an interested spectator.

We believe that only when industry is carried on in this spirit can it be successful and worth while.

H. T. HILDAGE.

T. G. MARPLE.

F. L. MEYENBERG.

March 31, 1938.

After more than twenty-five years' industrial experience and eight years' educational and research work in my native country, I may be pardoned if I felt qualified to write a book which deals with the subject of industrial administration. To-day, however, after more than four years' work in England, mostly in iron and steel works, I know that this could have been accomplished, as it is *now* presented to the reader, only because

a friendly fate brought about so close a co-operation with my co-authors.

If the book reflects British, American, and German knowledge and experience rightly synthesised, that is due to the work of my colleagues, who have not only contributed their own thoughts and experiences, but have given to it uniformity of language and an English atmosphere.

I would add an explanation of the fact that there is no bibliography of German books in this volume. Naturally I have used German publications to a considerable extent, especially in so far as I have been personally connected with them. The publications of the Institute of Work-and-Time Studies; of the German Standards Institution; and of the Institute of Cost Accounting and Financial Control, of which I have been Chairman for many years, and the investigations of my pupils, carried out under my control, are all quoted freely (see pp. 50, 101, 166, 227, and 271 *et seq.*). It seemed better, however, to omit a list of books useful only to those able to read German, and not always available even to them. But I shall always be pleased to answer the questions of those who desire information relative to German technical literature.

Finally, I may be excused if I use this opportunity to express my gratitude that I have found a home in this country. May my share in this book be a modest acknowledgment of my obligation to the British people.

F. L. MEYENBERG.

March 31, 1938.

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PART I
PRINCIPLES

INTRODUCTION

SINCE the beginning of the century there have been two tendencies in management, one consequent on, in fact made necessary by, the other.

Competition in all trades has become keener, and profit margins, if any, have become smaller; also customers have demanded better quality, and products have become more intricate and difficult of manufacture. Tools, machines, and plant have become necessarily more complicated and less easy to handle at maximum efficiency.

The first effect of the education of workpeople has been to make them realise their position and power in the scheme of things, and to demand a higher standard of living, and at the same time shorter working hours and better conditions. It has also helped them to an understanding and appreciation of the difficulties of management, and thus made them more ready to co-operate with those in authority.

All these things have made management more complex and more exacting, and it is interesting to imagine the "traditional" manager of the early years of the century confronted with the conditions faced by, and the demands made upon, the manager of to-day.

This increase in difficulty and complication has brought about the almost complete abandonment of the "instinctive" management of, say, 1900, in favour of more scientific methods, and has compelled the conscious study and analysis of the various factors and functions of management, and the adoption, in its exercise, of principles analogous to the "division of labour" rendered necessary by the complications of manufacture, and by the necessity for increased production.

Thus has modern management progressively armed itself to face its problems and perplexities, and whilst there have been mistakes and failures, yet, on the whole, considering the magnitude of the change, it has been accomplished not un-

successfully; this is perhaps partly due to the care that has been taken to maintain the correct balance between the economic, technical, and psychological factors. The relative importance of these factors varies, of course, with the nature of the undertaking, but it is essential that any matter under consideration should be looked at from each of these points of view, and as far as possible simultaneously.

One speaks of a "change" in management or in management methods, but really and truly the thing itself has not changed, and is not changeable. Management has become more effective because conscious thought has been superimposed on instinct, and new aids have been devised to meet the new conditions. Fundamentally, in any activity that employs human beings, management now, as in 1900, is leadership.

The manager of to-day may have called to his aid methods and systems as well as appliances unknown to his predecessor; he may have analysed his functions and delegated some of them to chosen assistants in order to reduce his own load, but in the last analysis he will succeed completely, partially, or not at all, according as he is able or unable to unite his own staff and the people they control in a single co-operative and continuous purpose; and his staff also will be more or less valuable to him according as they individually have within themselves the essentials of leadership, and can foster a healthy and happy spirit of emulation and personal effort without destroying co-operation, or causing friction or jealousy.

The principal purpose of the following pages will be to enunciate the principles on which the modern manager works out his salvation; to describe the various methods and aids that have been called into existence, and to indicate how all these are used, and the results of their application. Let it never be forgotten, however, that whilst scientific aids and systems are essential to success in modern management, the success with which they are applied will depend entirely upon the quality of leadership shown by the supreme head, and communicated through him to his subordinates, immediate and remote.

It is no more possible to define a leader than it is possible to define an artist, although it might be said that a leader is

an artist in his understanding and love of human nature and his handling of human beings. It may not be true that leaders are born and not made, but certainly the process of fitting men for leadership must start at an early age, for the process takes many years of training and experience. One can, however, name some of the qualities that go to make a leader, and platitudinous as it may appear, it will be as well to do so.

To control others, whether he is armed with authority or not, a man must have perfect control of himself; which does not mean that he must never lose his temper, but that he must know when to lose it, and when and where to find it again.

Apart from this, perhaps the qualities that will help him most to win and retain the confidence and trust of those he seeks to lead are loyalty, sincerity, and honesty. He must be unswervingly loyal both to those he serves and to those he leads; he is obviously a trustee for the interests of those he serves, and though not so obviously, yet not the less truly, for those he leads. Such a position would, of course, be impossible unless he were invincibly convinced that their interests were identical. It is unnecessary to enlarge upon the need for sincerity and honesty.

It is clear that he must, generally, have faith and trust in his fellow-workers, else how can they have faith in him? And he must seek to develop their good qualities and strengthen them at their strong points rather than concentrate on their faults and weaknesses. A gardener who spends all his time pulling weeds will never grow flowers.

The leader will know his immediate associates, those he leans on most, intimately and thoroughly; choose his method of handling each one of them according to each man's temperament and nature; and will choose these associates in such a way that the combination of their prominent or strong characteristics may produce a complete and well-balanced organisation. Each member of it will know, broadly, what his line of personal progress may be and how far he may go along it, and thus, without checking initiative or ambition, personal jealousies and friction will be avoided.

The most important of these qualities will be acquired in

early youth, and be strengthened as a man grows in years; the remainder will come as the result of experience gained from contact with men belonging to grades of society different from his own. Their relative importance will depend on the nature and magnitude of the undertaking, and no general specification can be given.

In the same way, the management aids and expedients to be used must be chosen and proportioned to the purpose for which they are to be used. Whilst it is necessary to mention all of them in this book, and perhaps, by mentioning them all, make them appear of similar necessity and importance, the reader must not be misled into thinking that they are, but must be prepared and able to select and adapt the means to suit the particular end he has in view. For this reason, stress will be laid on principles, and the aim will be to make these principles clear and well understood, in order that their relative importance in any particular case may be better estimated.

The modern management has been called "scientific" management, chiefly because this term was used by F. W. Taylor in connection with the proposals he made for assisting and intensifying management and control; perhaps he used this term to distinguish his methods and systems from the traditional management, and perhaps also because these methods had a scientific or pseudo-scientific aspect. Of course, Taylor's methods were neither "scientific" nor, by themselves, "management." Management is not, and cannot become, scientific until psychology—the science of human reactions—has made such progress that human beings can be analysed and classified, and the laws that govern their actions and thoughts be accurately stated. Management is, above everything else, the art of handling, controlling, and utilising to the full the abilities and efforts of human beings.

The only reason for this criticism is that the term has gained some currency, and it must be confessed has aroused some prejudice. It is, however, a trivial and unimportant matter. Taylor's work is of great importance and of enduring value to industry; and his right to a place in the halls of industrial fame is based on something much more substantial than the claim to have founded a new science. It is based on his

pioneer work in propounding and advocating the conscious, systematic, analytical study of management problems, and in showing how to carry such study to fruition.

But to return to our subject, the modern manager clearly recognises and distinguishes between three different aspects of every piece of work, and these may be called the technical, the economic, and the psychological. In considering the technical aspect, one is concerned in deciding what result one desires to produce, how to produce it, and what equipment is the best for the purpose. The economic aspect relates to the cost incurred, as to whether it is kept as low as possible, and the return obtained; and whether that return is sufficient to cover the cost, and thus enable the work to continue. As already indicated, psychology deals with what has been called the human factor, which is perhaps the most difficult to guide and control perfectly, and yet the one that brings the richest success, in the quality, quantity, and cost of the result, and in other even more important ways. A simple example will show that, though separately recognised and considered, these three features are not independent, and must always be considered simultaneously.

It is required to produce, from a rough board, a piece cut to specified size, planed and polished. The work can be carried out in various ways, and with various equipment, and the result will depend as regards accuracy, finish, and cost on the method and equipment used. The aim is to do the work just well enough to suit the purpose for which it is required and at the lowest cost, and therefore it is necessary to arrange all the circumstances of the work so that, his rightful requirements being met, the worker may use his best efforts. Thus the technical, economic, and psychological requirements are satisfied, but to satisfy them is not always quite so simple and straightforward as it seems. The worker may have a preference for one way of working, and in view of his experience he may be right, but, on the other hand, he may be wrong, and if he is wrong how is he going to be over-ruled and still be induced to put forth his best efforts? There may be doubts as to which is more important, accuracy or finish, and if one obtains the best of both the cost may be too high. Indeed, the question of cost may of itself decide the method and

equipment to be used. All or any of these questions, and others, may and do arise in any job, especially if the work and the processes are complicated and numerous. So that, whilst there are the three distinct points of view with regard to any piece of work, they are interdependent, and must be taken together, and not separately.

Again, good management is not concerned alone with the execution of the job in the works; materials and supplies must be purchased, at the right time, in the right quantities, of the right qualities, and at the right prices. These things must be stored in readiness for production, and issued as required against authorised drafts, and there must be no loss or wastage of any kind. The goods manufactured must be marketed, either before, during, or after manufacture. The whole of these processes must be financed, accounts must be collected and paid, and so on. The fundamental principles of management apply to all these activities, and it is the aim and function of management to ensure that they shall be efficiently and effectively carried on, and be co-ordinated to secure satisfactory production, as tested, measured, and judged by the stability and success of the undertaking as a whole.

In the following pages, indications and general guidance are given in all these matters to the best of the ability and experience of the authors, in the hope that they may be of some assistance to the manager in his work.

The title of this book is *The New Management*, and this introductory chapter is an endeavour to show in just what respects the title is justified. The essence of real management is leadership, and on a later page we say that leadership is as old as the human race. Work and time studies and planning have been known for forty years, though not quite so long in this country. Costing, of a kind, has been known even longer. Mass-production is as old as the manufacture of motor cars. Although these things have been known and practised for so long, can it be said that they have always been practised as aids to leadership—that is, to unite the whole personnel of an undertaking in a single co-operative and continuous purpose? Or, have they not sometimes been used in a partial and unbalanced way in attempting to secure from the workers service which it has short-sightedly been assumed

they would not give willingly, or even to compel such service?

Since the days of F. W. Taylor, and the early days of Henry Ford, much progress has been made in developing the technique and use of costing, time and motion studies, progress planning, and even store- and stock-keeping, as well, of course, as in improving manufacturing equipment. But more—much more—than this has happened. A new spirit in management has arisen. There has been a widespread and steadily growing recognition that workers are men and women, who cannot and will not be bullied, driven, and exploited, and who of their own innate goodness will readily acknowledge the call of duty and loyalty, and respond generously to fair and considerate treatment. And there is even some evidence that it is coming to be recognised that appeals to cupidity will not succeed any better with free agents than the constraint of fear; in other words, there are signs that “incentives” are beginning to be considered unnecessary, if not harmful.

On the other hand, it is also recognised that the best manager is not necessarily the busiest and hardest-worked manager; that a good manager will free himself from routine and detail by the proper use of such mechanical, systematic, and other aids as have been devised for just this purpose; that he will be the master of his own time, choosing what particular work he will do, and when; and will thus have leisure to make well-considered decisions, and to study and know thoroughly his subordinates and their work.

It is these developments that have appeared that are referred to as the New Management.

CHAPTER I

FACTORS OF ECONOMICS

MATERIAL, LABOUR AND CAPITAL AND THEIR CONNECTIONS WITH EACH OTHER

IN order that the purpose of this book may be fulfilled, it is necessary to deal with management as a whole, and to show how the parts are related to and react upon one another; it will not suffice to treat the different branches and functions in a series of detached and unrelated articles or chapters. Therefore an explanation of the fundamentals of economics is given here in the beginning, and referred to later when it seems appropriate, so that its part in the plan of things may be seen. The relation of economics to management may be regarded as analogous to the framework that binds together the foundations, walls, floors, and roof of a building.

Naturally, some only of the essential features are mentioned, and discussed neither in detail nor exhaustively. Those readers who have already made a study of economics, and those who wish to proceed at once to a study of management, may omit this chapter in their first reading, but should return to it afterwards.

For the purpose of considering the connection between a single industrial undertaking and industry as a whole, it is convenient to picture the former as a building into which different things enter through the same or different doors, and the same things, altered as to shape, size, or other qualities, go out at the same or preferably other doors.

The sum of all such buildings, each an industrial undertaking, represents the whole industry of a country. This moving of goods forms the relation of one part of the economic life of the country to another. Looking at the matter from the point of view of a single industrial undertaking, material and goods enter from the primary purchase market, and pro-

ducts are delivered to the immediate sales market. The first is formed of the suppliers; the second by the customers of the undertaking. Both parts are divided into two groups: the original production and the primary industry on the one side, and the secondary industry and the consumer on the other. Fig. 1 shows this and illustrates the direct connection with the entire industry.

But how are all these things treated in the industrial unit when passing through it? If it is a manufacturing and not merely a distributing unit—and this book is concerned only with the former—the goods are changed in passing through the works: “Raw Materials” entering into the factory become “Products,” and are delivered as “Goods” to the customer. But two things are necessary to achieve this change: “Labour” and “Capital,” the latter being represented mainly by buildings and machinery, the money to pay wages and salaries and other expenses, and to purchase raw materials. Thus the undertaking is seen to be founded on the three fundamental factors of economics: materials derived from nature, labour, and capital. These three factors persist through every stage of industry from the very first to the very last; that is to say, from the wresting of the raw materials from Nature to the delivery of the finished goods to the ultimate consumer. If the first raw materials are minerals, the original land or royalty owner represents the supplier, and labour and capital are necessary to “work” the land, and to pay for the right to work it and the expenses of doing so; if the first raw materials are of animal or vegetable origin (as in agriculture and allied industries), the original landowner stands in the place of the supplier of materials, which in this case are latent.

Now, these three factors are neither similar nor are they independent of each other. The materials, or the means of producing them, given by Nature, have no value by themselves. Only by the labour of men, either in changing their structure or their situation, and the use of capital, does value result. That will be clear from the example of coal, which is without any economic importance until it is mined, cleaned, and brought to the place where it is to be used. Money is not an original product of Nature, but is an invention of men to afford a measure of value, and a medium for exchanging

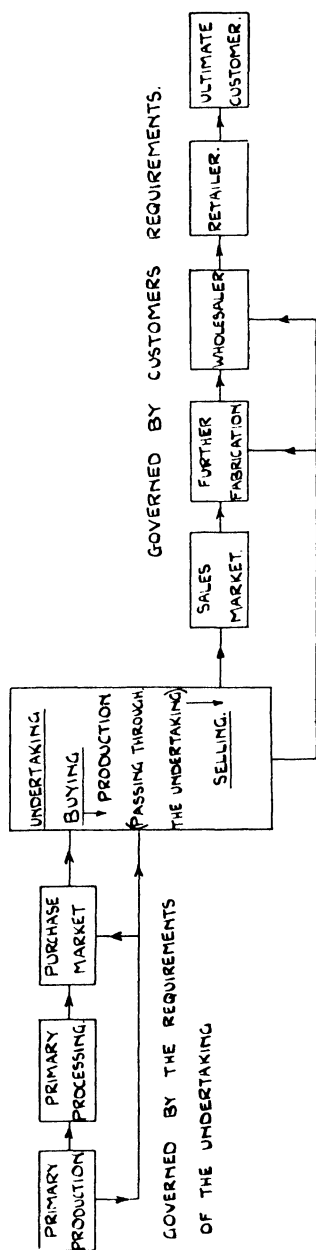


FIG 1 TRANSITION OF RAW MATERIAL INTO GOODS AND THEIR SUBSEQUENT DISPOSAL

labour, products, and materials. It is not necessary, for the moment, to consider the imperfection of this measure of value; that will occupy us later. Therefore in the last analysis it is the labour of man alone which gives a product its value, since the machines and tools used were also themselves produced from natural materials by labour.

This simple but tremendous fact affects every feature and aspect of our social life, and, like some other fundamental facts, is apt to be lost sight of, or at least not fully realised.

The cost of a manufactured article or product is shown broadly and simply by the following equation :—

Cost of Product = Cost of Raw Material used + Cost in Wages paid for the working up of the material, used directly in production + Additional Costs, not included under labour and raw materials, but nevertheless necessary, and usually grouped and called Overhead Charges.

It is seen from an examination and analysis of the items on the right-hand side of this equation that they consist entirely of labour. In the case of the first—materials—this has already been shown. In the second it does not need to be shown. The third consists partly of material and wages and partly of other costs that may appear at first to have nothing to do with labour, but ultimately are seen to be nothing but labour. Take, for instance, one such item—depreciation of plant or machinery. This important item in overhead costs, calculated as a rule as a percentage of the original cost of the equipment, or its present book value, is set aside year by year to cover the wear and tear and obsolescence of the machinery or plant, so that when it is worn out or obsolete there may be a fund to replace it, and the capital in the concern be maintained intact.

It has already been shown that capital is the accumulated product of labour previously performed; depreciation is the further accumulation of the product of labour to conserve or replace capital.

Insurance (fire, boiler, accident, etc.), is another overhead charge. It does not need much thought to show that the charge for insurance is precisely similar to depreciation.

Sickness and unemployment insurance are part of the wages of labour. Commercial or selling expenses are almost exclusively payment for services rendered. Management and administration charges are also payment for services.

Even local taxes, which constitute payment for educational services, sanitation, police protection, and the construction and maintenance of roads, can be shown ultimately to be for service or labour. And thus, however far we carry the examination, we see always that, apart from the beneficent contribution made by Nature, either in storing minerals in the earth for our use, or in providing for the growth of vegetable and animal matter according to laws and seasons, everything that is of value added to these provisions requires the expenditure of labour both manual and mental.

EXCHANGE ECONOMICS

Originally each primitive man provided completely for the primary needs of himself and his family—food, shelter, and clothing.

At some stage it must have become clear to, and accepted by, the thinking members of a community that it would be to the advantage of all if each individual produced only those things, or rendered only those services, for which he had special aptitude or facilities. This beginning of civilisation required some means by which each man could complete his own requirements by exchanging the surplus products of his work for the products of the work of other men that he needed, and so the change was made from single economics to exchange economics, and thereby came about the beginning of the division of labour, which, in increasing specialisation, is the essential feature of modern industry.

In the development of exchange economics, a measure was very soon adopted to compare the different goods exchanged, for how otherwise could different foods be compared with each other, or with garments, or garments with weapons, and fair exchange be assured? Thus from exchange economics there was a transition to "exchange-medium economics," *i.e.* exchanges were no longer carried out directly, by barter, but by

the use of a medium measured by a common unit, "money." As, however, we have seen that all goods receive their value originally from men's labour alone, it would be more accurate, but not as convenient, to use labour as an exchange medium, supposing that labour could be measured by a common standard or measure.

THE MEASURE OF LABOUR

And so arose the problem of finding the right measure for men's labour—a problem as old, perhaps, as mankind itself, but not yet solved perfectly or logically, in spite of all the efforts of successive generations using all kinds of methods in all kinds of different activities. Anyone who has ever tried seriously to solve this problem can have no doubt that its intractability is due to its intrinsic difficulty, and to the present imperfection of human science.

What is required of such means as are employed to measure two different things—that is to say, to compare them with each other so that the degree of difference is made clear? First of all, it is apparent that two things different in kind or form cannot be measured with the same rule, just as a school-boy learns that it is impossible to add five apples to four pears. The question is, therefore, whether "men's labour" is similar enough to be compared by the same measure. The difficulty is that the capabilities of different men affect their work in very different ways—capabilities which are derived from the union of body, brain, and spirit in the human being in a very complicated manner, and which are influenced now by one, now by another, and now by all three elements of the human organism. We can realise, therefore, why no one has been successful in finding a perfectly fair measure for men's labour. The way in which the three human factors work together cannot be gauged exactly. Here, quite clearly, is one example of the inappropriateness of the name sometimes given to our subject—"scientific" management. Being under the necessity to do in some kind of way a thing incapable of exact and logical execution, we fall back upon the method that is most acceptable and the nearest approach to accuracy, and are really in error only in calling it something that it certainly is not.

TIME AND SKILL

It should be emphasised that the point so reached in the solution of the problem cannot be regarded as final, but merely as the best approximation to a solution available at present.

For instance, we know that a man with a certain aptitude in a particular direction can do a job in a certain time. If the same work is done by two men with different aptitudes, one will take longer than the other. Because there is a common measure between the two men—viz. *time*—we say, for example, that a man who can do the work in half the time is twice as good as, or has double the skill of, the other, and this statement would be sufficiently accurate for all purposes of fixing value, or for remuneration. It would be incorrect, however, if we were to apply that conclusion to any other kind of work, for there is no one kind of work which requires only one form of skill in a man. The human being is not simply a piece of mechanism in which one function can be separated from another and considered separately, but a very complicated organism following laws about which we still know extremely little.

VALUE OF DIFFERENT KINDS OF WORK. MONEY AS MEDIUM

To repeat, we should commit no fault, or at any rate no intolerable fault, if we used time as a measure of men's labour only when the work performed was alike or nearly so. But if we proceed to compare different work, or to add numerically the measures of different work, we have to adjust or to multiply our factor by another representing the value of the difference between the two kinds of work, and the latter factor is unknown and cannot be found, but must be estimated, or fixed arbitrarily in some way or other.

To take an example drawn from engineering practice; assume three different jobs done on three different lathes each occupying exactly the same time, say, thirty minutes. One man can do the first with a simple lathe; special care is perhaps necessary for the second, for which a very small tolerance of inaccuracy is prescribed to suit the requirement of fitting it into another part, or for some other reason; the

third needs intimate knowledge of a special apparatus on the lathe and of its handling. In these circumstances, it would be absurd to say, either that the economic value of the three jobs was $30 + 30 + 30 = 90$ minutes, or that the three jobs were of equal value.

Possibly the second man's work could be judged to be worth 25 per cent. more than the first man's, and the third man's work perhaps even 50 per cent. more, so that the calculation would be $30 + 1.25 \times 30 + 1.5 \times 30 = 112.5$ value units, and some such judgment is used in fixing the payment of the men. If we pay the first workman a wage of $8d.$, the second will have $1.25 \times 8 = 10d.$, and the third $1.5 \times 8d. = 12d.$ The three jobs together are therefore worth :

$$8 \times \frac{30}{60} + 10 \times \frac{30}{60} + 12 \times \frac{30}{60} = \frac{900}{60} = 15d.$$

It is apparent from what has been said that this transition from time to money is not so simple as the example makes it appear. First there is the real difficulty of putting the work of one man in the right relation to that of another, as well as in the right relation in respect of the economic value it has to the undertaking. Consider how difficult it is even in so simple an example where we had only to compare the work of one lathe-hand with that of two others. Even in that simple case all the complex characteristics of humanity come into play. How much more difficult it will be with widely divergent kinds of work, such as that of a lathe-hand, an instrument-maker, an artist, the manager of a modern workshop, and a salesman.

It would be quite useless to approach this problem with scientific weapons; in fact, there is no standard by which the value or relative value of work or service can be really measured or compared, and so, in practice, the matter is left, more or less, to settle itself in accordance with a variety of factors and conditions, provided only that the settlement is acceptable to all concerned. The lower grades of workpeople are paid according to the cost of living and their needs, and the relative demand for and the supply of workers governs their ability to maintain or enforce a fair standard. To some extent the law of supply and demand is manipulated by the

collective withholding of labour, or the threat to do so; or by the opposing collective withholding of work, the workers' sole means of livelihood. This, of course, is all wrong, productive as it is of exploitation, strife, hardship, and bad feeling. But, in spite of this, progress has been made, and there is a growing tendency towards a rational method of settling such matters by discussion, negotiation, and compromise, and towards a higher standard of living, shorter hours, better conditions of work, and perhaps towards a more accurate and logical solution of the problem. It is fair to say that these tendencies have followed the higher education of the people, and their discovery that they are more powerful in unison than as individuals. It is rather surprising and greatly to their credit that the workers have not more often abused or sought to abuse their power, and that it has usually been possible to avoid the serious injury to individual industries that would result from demands for the sudden and extravagant improvement of conditions. The inability of trade unions to amass sufficient funds to finance long strife, the inherent reasonableness of both employers and employed, and even the play of disinterested public opinion have all been moderating factors.

In the higher grades, and in the salaried ranks, where there has been little attempt at collective action, the law of supply and demand has roughly settled the terms of employment.

Many efforts have been made in the past, and to some extent these efforts persist, to modify the basic payment or reward for service in an apparently scientific manner.

These have generally had a measurement of some kind for a basis, with a more or less complicated calculation, as a result of which the workers receive an additional payment for additional work in something less than the same, or a fair, proportion; but none of them has had a durable success, and some have resulted in embittered feeling between workers and managements. These various "incentive" systems can be said to have failed (*a*) because, being usually unfair, the workers have discovered their unfairness, or (*b*) because they have been too complicated to be readily understood by them, or, perhaps, (*c*) because an appeal to cupidity is not the best way to induce rational beings to give of their best.

This statement requires to be qualified somewhat, since in some industries "straight" piece-work—that is, payment in strict proportion to the amount of effect produced—or a composite basis of fixed wage plus a payment in strict proportion to output, are still accepted as the standard method of wage-fixing.

Although the diverse valuation of labour is recognised by means of variations in wages and salaries, and there is no perfect standard by which the values can be ideally and logically measured and compared, it does not follow that this unsatisfactory condition will continue for ever, and that no attempt will or should be made to find a satisfactory solution of the problem. Quite the contrary. In this, as in all other matters, it is the imperative duty of managements to seek progress, by every means available, towards the ideal, which in this case is nothing less than absolute justice for all workers, and as between the different groups of workers; and to see that the rough-and-ready measures unavoidably used meantime do not inflict patent hardship and injustice upon them. Indeed, progress is constantly being made, sometimes so slowly as to be almost imperceptible, and sometimes more rapidly. This is one important aspect of social progress, whether it results from conscious inquiry and research as a logical process, or by the apparently haphazard and illogical play of the forces already mentioned, and others.

VARIATION IN THE VALUE OF MONEY

One of these "other forces" is the variation in value of the measure adopted as a standard of value. Mistakes are often made in fixing standards, due to the crudeness of the measuring instruments, discoverable afterwards when the instruments have been improved. A notable example is the standard metre, which was intended to be $1/40,000,000$ of the length of the meridian through Paris, which, with more exact means of measurement, has been found not to be the correct proportion. No practical person suggests the altering of the standard metre, since no great advantage would result, and the cost and inconvenience would be enormous.

This is not quite the case where the measure "money" is

concerned. This measure was adopted at the beginning of exchange medium economics as a common denominator for different values, *i.e.* different goods, or products of different workers' labour.

Unfortunately, that is not the only characteristic of money. It has also a commodity value for various non-monetary uses; it is liable to be withdrawn from its proper work as the exchange medium and hoarded; its supply from the mines is inconstant. Further, it is ill-distributed amongst the nations; and, besides its use as the actual, or the supporting, exchange medium for a country's internal trade, it is the exchange medium for the country's trade with foreign nations, each of which has a currency differing from every other in denomination and value. For these reasons money is an imperfect measure. One of the chief tasks of Government is to provide, so far as it can, a stable currency.

These characteristics of money offered no insuperable industrial handicap, at least in modern times. But national and international policies pursued by the nations subsequent to the Great War have made the matter of the exchange medium, particularly in its international aspect, a major world problem which must be solved if the political and economic well-being of the nations is to be regained. So great has been the effect of these policies, imposed by economic necessity or deliberately adopted, that for long periods during the post-War era industry all the world over has been reduced almost to impotence.

This, however, is not the place to explain in detail the monetary economy of the world, and why the value of money should change. It is sufficient for our purpose to remark that as a commodity money is subject to the same changes as generally affect all other commodities. The "Purchasing Power" of money is said to rise or fall when the alteration in its exchange value is operative over the whole range of commodities; but, apart from any rise or fall in the general purchasing power of money, the "selling prices," or the demand for particular goods, may vary. Such changes, due to non-monetary causes, can be expected in some cases, foreseen in others, and although they are incapable of control may usually be provided for.

Considering the problem from the point of view of the variations in the selling prices of particular goods, we must take into

account the fact that the esteem in which goods are held by prospective purchasers changes with fashion, climate, season, and weather; that it varies from one country to another and in different parts of the same country. There are sudden changes and gradual changes, and they all affect the exchange value in money—that is, the selling price of the goods. They do not themselves affect the amount of labour involved in the production of them, nor the time during which that labour is exercised. Neither do they, of themselves, affect the amount or quality of material used to manufacture them, although they may subsequently or consequentially affect its purchasing price. These uncontrollable changes “of the markets” constitute again a great danger to a competently managed business, and the avoidance of it is a good deal like navigating a small ship amidst the shoals and breakers of coastal waters, where watchfulness, foresight, resourcefulness, and prompt action are necessary.

Gradual changes give their own warning, and protective action may be taken. This action may be the re-design of product to offer greater attraction to prospective customers, or to lower cost of production; or it may be a careful and detailed scrutiny of every process of manufacture, of marketing, or of administration for the same purpose; or it may even mean a partial or complete change of the product.

Sudden changes of magnitude do not often occur, and the best provision for them is the accumulation of liquid reserves of capital, and a conservative policy in the matter of stocks, both of raw material and of finished goods. Thus the changes in markets and the demand for goods may be controlled to some extent in advance, as already indicated, instead of being awaited and met when they occur.

A FAMOUS EXAMPLE

These references may be fittingly closed by the brief relation how a famous organisation discovered, only just in time, a very serious mistake in policy and recovered from it.

The first pattern of Ford car was well designed for service, well built of the best materials obtainable, and was sold at such a low price as to command an enviably large market.

With only minor changes in design and finish, it was produced year after year, and the company were naturally reluctant to abandon a model that had been so successful from every point of view. Other motor-car builders copied Ford methods, but changed their designs more frequently, and more completely, and this developed a taste amongst car buyers for something more sightly than the Ford, and a desire for variety and change even at a higher price, which the Ford Company would not and did not attempt to satisfy. The design and manufacture of cars were being rapidly developed by other makers, and the Ford Company stood still and was left behind. During the last two or three years of its production, the sales of the old model fell off considerably, and for some time it appeared to outside observation that the Ford Company was beaten by fashion and by its competitors, and would never recover the market it had created and lost. Apparently, the danger signal was seen just in time. New designs were made and put into production, and new models appeared. These were more in line with the public taste of that day, but did not seem to become as popular as the old model had at first been. It looked as though they had been produced two years too late for Ford to maintain or recover his lead. After a year or two the V.8 was produced in the United States, and a little later in this country, accompanied here by smaller 4- and 6-cylinder models. These changes in policy, and their brilliant execution in management, achieved the desired result, and Ford "came back."

CONCLUSION

What is the result of this consideration of the problem of the evaluation of work or labour? It has been made evident that time is a perfect measure of amount, but not of quality. Money, which should be used to correct the deficiencies of time in this respect, is not itself a stable standard. No other means are available or in sight, and so the evaluation of labour and of goods remains for the present one of life's problems which have no general and logical solution. It provides opportunities for the exercise of those human qualities, judgment, goodwill, and forbearance, that go to make our common life and civilisation possible, without which it would be mere existence, dull, drab, and profitless.

CHAPTER II

ORGANISATION

WE have spoken of the principle of the division of labour which marks the transition from single economics to exchange economics, and have suggested that this principle, pursued as far as it is economically possible, is the most significant characteristic of modern industry. Really this principle applies not only to labour and to manufacturing operations; it operates also over the whole field of management and control, but, in that sphere, it is generally referred to as the division of functions or duties. There thus arises the necessity for assigning to different individuals their respective duties, instructing them how those duties should be carried out, and arranging the conditions so that they can be carried out effectively, and in correct relation to the execution of other duties with which they are connected. This is the work of organising, and the consequent arrangement of personnel by their duties is the organisation of any particular concern.

MEANING OF THE TERM

Before proceeding to consider this matter, it is desirable to explain more carefully what is meant by organisation, because it is a word that is not always clearly understood and is sometimes misused. For example, it is sometimes thought that the value and effectiveness of an organisation depend on the number of mechanical "systems" it has, for ensuring automatically that certain things shall be done at certain times, or for fixing responsibility for failures, whether such "systems" actually work or not; on the number of forms in use, whether they are or are not adequate to the purpose they pretend to serve, useful or not useful; on the volume of statistics collected and furnished, and whether they are supplied with due despatch; or, when they merely represent history,

whether they are or are not accurate in themselves and accurate in tendency, and are, or are not, the statistics really required. But, in fact, provided these things are sufficient for all purposes and of the right kind, the less there are of them the better, not only because they are costly and an excess of them is wasteful, but also because they tend to produce rigidity where the utmost flexibility is needed, and because they almost inevitably lay the emphasis in the wrong places.

These things have little or nothing to do with organisation, and although the producer of them may be, and often is, called an organiser, in a great number of cases he might just as truthfully be called a dis-organiser.

An organisation could be described, not inaptly, as a machine, of which the working parts are living and thinking human beings, each with his own function to perform, and performing it regularly, faithfully, and completely; and reacting on his colleagues, the other parts of the machine, if he reacts on them at all, in such a way as to be in perfect harmony and step with them, each member of the organisation being complementary to the others.

The work of organising—that is, the building of such a machine—consists, first, in the selection of its members. These must be chosen not only from the point of view of their ability to discharge their own functions satisfactorily, but also with due regard to the fact that, as members of a team, they will be required to work harmoniously together, so as to be complementary to one another and the whole scheme of things. They must not be of a standard type, but of various types, in order that one member may be able to lend strength to another at his weak points (and they will all have some weak points), and not clash with him at his strong ones. Secondly, they must be accorded the conditions necessary to enable them to work at their best, and be instructed in their duties, particularly as to the limits of their functions at those points where they make contact with or influence their colleagues. Each should have a possible path of promotion pointed out to him, and be given some indication of the distance he can travel along it. This will enable him to realise that his personal success depends on the success of his fellows and of the concern as a whole, and help to avoid jealousy and

friction, and promote smooth working. This preliminary work of organisation is naturally best done by the manager, who himself gives character to the machine, and who has to use it; and he will require to give it continual attention and adjustment, so that it may cope satisfactorily either with stable or changing conditions.

Thus it is one of the functions of a manager to organise. There is no distinction between a manager and an organiser, and it is not easy to explain how the term "organiser" came to be appropriated by a particular class of men. Certain people with a flair for that kind of work were selected to invent, design, and build systems and methods of one kind or another to *assist* management. So far, their work was useful and valuable. It was only when they became "professional" organisers, and besides carrying this work, which they understood, to excess, began to meddle with things which they neither understood nor were temperamentally fitted to understand, that mischief resulted.

A short definition of organisation, and one that refers more to its result than, as the above explanation does, to the work itself may be added.

"Organisation is the art of using the advantages of the division of labour necessary in industry, and of simultaneously avoiding the disadvantages connected with it, as far as possible in the given circumstances."

ITS DEVELOPMENT

To illustrate further, we may follow the growth of an organisation as it were from the seed.

In a very simple organisation—a one-man concern—the owner may perform all functions, buying the raw material, and making it into the "goods," which he sells and delivers.

When the business grows beyond the capacity of one brain and one pair of hands, the sole owner begins to employ others, at first in the manufacturing department, because this is the department around which all the others are gathered, and afterwards for other work not directly productive, some of the new employees relieving him, the head, of such of these duties as he is no longer completely able to fulfil. The selection

and training of this portion of the staff are really the beginning of organisation, and since it is not directly productive, although still necessary for production, its growth will be watched with a jealous eye, lest it grow out of proportion to that part of the organisation which is directly productive.

This beginning of the division of duties continues. There will follow the addition of foremen, first according to the number of divisions or classes of labour, afterwards according to the number of operatives in each class. Then, the business continuing to grow, specialists will be selected and trained, for selling (with all its subdivisions); for buying; for the designing of product, and of process and method of manufacture, as well as of appliances; for the inspection, both of raw materials to ensure the possibility of correct manufacture, and of product to ensure the quality of workmanship at each stage, and in the final product; planning, to secure the orderly and punctual execution of the work at each stage, and to furnish the selling department with information as to the extent to which the works are committed, so that it knows which class of work to seek orders for, and what delivery it can promise; costing, to enable all concerned to see where economies can be made or efficiency increased; and finally for administration.

In all this, it is to be noted that each devolution of a duty by the head, and each increase of staff, will have been shown to be imperatively necessary, and in consequence the organisation will be in exact proportion to the needs of the business. This makes for efficiency, as well as economy, and is perhaps one of the reasons why businesses which have grown from small beginnings prosper more completely up to a certain point of their development than larger concerns. The limit is reached when the concern grows beyond the capacity of the founder to control it. This is the critical stage in growth. To build up an organisation for a concern initiated on a large scale, however, is always more difficult; the guidance given by necessity is lacking, and the only safe rule to follow is to commence with a skeleton staff of minimum dimensions, chosen, trained, and tested with the greatest care, and add to it as the needs arise.

No rule can be stated that will indicate the size, form, or kind of organisation necessary in a particular case. Every concern is different from every other, even in the same industry,

and the organisation must be designed specially to suit its individual needs. Some description and definition of each of the activities of the organisation is given below, but their relative importance, and the means adopted to carry them out, must vary with the undertaking.

Speaking generally, there are two broad classes of activity : production or manufacture, and commerce. It will be readily seen that one class, manufacture, is almost entirely internal, and the other, commerce, as the word itself indicates, is concerned mainly with the world outside the works.

Raw materials are brought from supply markets to the works. They are there manufactured and converted into products or goods, which are sold, and delivered to customers. There are, of course, undertakings in which the material dealt with is unaltered, and resold without change of form ; indeed, there are some merchants who never even see or touch the goods they deal in, arranging for them to be delivered direct from the producing source to their immediate purchaser. These are sales, distributive or merchant organisations, and are not of interest for the present purpose, although they form a link, and usually a useful and necessary link, in certain industries, and are a part of the whole organisation of the particular industry they serve.

The distinguishing feature of the kind of undertaking under discussion is that it changes, manufactures, or expends useful work upon the raw materials it purchases.

ITS PRINCIPLES

The division of functions into two classes, production and commerce, is only for convenience, and does not imply any real division or cleavage within the concern. They are necessarily interlocked, and the closer this interlocking and the more intimate their relations, the more successful the business. This inter-connection is usually secured and emphasised by the appointment of a single head, with some knowledge of both kinds of activity, and the ability to control those who exercise them, and to co-ordinate their work. This office is that of the general manager, who is directly responsible to the executive board—that is, to the

Board of Directors, or the partners, if the concern is a partnership. To the staff and employees he represents, and is, the instrument of the owners; to the owners, however the unit is incorporated, he represents the staff and employees. In a Company, he may have a seat on the Board, which increases the intimacy of his connection with the Directors, and gives him a voice in determining policy, and then he is Director and General Manager, or Managing Director. It is his functions as Manager that are referred to here.

Without such co-ordination as he exercises, the commercial departments and the production or manufacturing departments and their heads may drift apart, or even into rivalry and antagonism, and this must be avoided at all costs. A board or committee can neither control adequately nor co-ordinate; and, obviously, individual units cannot co-ordinate themselves or their activity. That is work for one individual.

What is meant by co-ordination? To unite all efforts and concentrate them upon the common purpose; to guide those who exert these efforts in their contacts and discussions with one another; and decide, reconcile, or, better still, eliminate by conviction, their differences. The duty of co-ordination does not necessarily imply an expert knowledge either of commerce or production, and in general it is better that there should not be a bias in either direction. Occasions will arise in which the interests of the commercial department appear to be opposed to the manufacturing interests, and one must give way to the other, since the thing that matters is the general good. Co-ordination does, however, imply the ability to weigh evidence and arguments, to distinguish between solid knowledge and mere debating ability, to probe and sift until everything has been laid bare, and *to know when this stage has been reached*. It also implies an intimate knowledge of the characters of the men concerned, and the ability to remove differences by conviction, if possible, and if not, to make decisions and get them accepted willingly and loyally, without engendering feelings of defeat on one side, and of triumph on the other.

Recapitulating :—

(1) The organisation should be as small as is compatible with the full discharge of all duties or functions, none being overlooked or neglected, and none over-emphasised.

(2) It will be divided into two principal parts: manufacturing and commercial.

(3) It must be managed—that is, handled and controlled—by one individual, and he must, if possible, be free from any bias or leaning, but guided only by the policy of the directors or owners, and the best interests of the concern.

(4) It must be so staffed that each member shall discharge the function or functions best suited to his character and temperament, and not be made responsible for more people than he can properly guide and control.

(5) Friction and jealousies must be avoided by closely defining the limitations of control and responsibility of each member. At the same time there must be sufficient overlapping to cause the members to feel both individual and collective responsibility for success or failure, as well as a personal responsibility in their own particular spheres.

(6) Both the head and the individual members of the staff must be so selected that differences can as far as possible be removed by conviction rather than by decision.

(7) While each individual member of the staff must be a specialist in his own functions, he must not be so narrow a specialist that he cannot appreciate other points of view than his own, nor so rigid in his views that he cannot modify them to suit changing circumstances.

(8) It does not matter greatly whether the man is chosen to suit the functions, or the functions to suit the man, so long as there is no great incompatibility.

(9) The whole organisation must be so moulded as to be adequate to the work it has to do, and to suit the particular genius of the manager. It must have some flexibility, and be capable of modification to meet the changing needs or tendencies of the business.

EXAMPLE OF AN ORGANISATION

As simple and obvious as these principles appear to be when stated in broad outline, as difficult is their successful and reasonable application in practice. Therefore it may be useful to explain them in greater detail, and with relation to an example which can be regarded as typical of many undertakings of

MANAGEMENT.

MANUFACTURE				COMMERCE & ADMINISTRATION			
DESIGN	PLANNING.	PRODUCTION	INSPECTION.	COMMERCE	ACCOUNTANCY	GENERAL ADMINISTRATION	
a. PRODUCTS b. TOOLS ETC. c. METHODS & PROCESSES.	ANALYSIS OF ORDERS.	PRODUCTION SHOPS	STANDARD - ISATION.	SELLING.	CASHIERS OFFICE.	LEGAL MATTERS.	
DRAWING OFFICE .	WORKS ORDERS.	AUXILIARY SHOPS MAINTENANCE ETC	INSPECTION OF TOOLS, GAUGES AND JIGS	PUBLICITY	WAGES OFFICE.	COMPANY BUSINESS	
LIBRARY OF DRAWINGS AND TECHNICAL WORKS	TIME PLANNING.	WORKS LABOUR OFFICE	TESTING OF RAW MATERIALS	PACKING AND DELIVERY.	STORES CONTROL	TAXES AND INSURANCES.	
TRACING AND PRINTING.	PROGRESS	SAFETY SERVICES.	PROCESS INSPECTION.	BUYING	INVOICING.	PERSONEL MANAGEMENT.	
TOOL ROOM & EXPERIMENTS			FINAL INSPECTION.	CORRESPOND- ENCE	BOOK-KEEPING.	WELFARE.	
					COSTING	TYPEWRITING AND FILING.	
					STATISTICS		

FIG 2. PLAN OF ORGANISATION OF A FACTORY

moderate size. It must be remembered, however, that it is only generally typical of one class of undertaking, and that while there are innumerable possibilities of variation in the organisation scheme, only one scheme is suitable for a particular case. For this reason, what follows must not be regarded as an exhaustive description either of the functions or of the way they are combined. Referring to Fig. 2, the organization may be described as follows :—

I. MANUFACTURE

On this side the principal functions will be :—

- (1) Design (a) of Product,
(b) of Plant, Tools, and Means of Production,
(c) of Methods and Processes.
- (2) Planning the order of work, and the time within which it will be done.
- (3) Production, *i.e.*, the Control and Carrying out of Operations and Processes.
- (4) Inspection and Testing of Product.

In a large undertaking it may be necessary to have a department or a single man in charge of each. In other cases it may be possible or necessary to group several of them under one control. For example, all designing may be done in one department. Planning and production might be grouped in another. Inspection and testing may go with design of product, or with design of methods and processes, or with production, or remain independent, according to the position that quality occupies in the policy of the concern, or according to the characters of the men in charge of the departments.

(1) DESIGN

(a) **Product.**—The “product designing” department settles the character of the product of the factory in all details. If it is an article or an appliance, the department furnishes drawings giving the shape and dimensions, with permissible limits of inaccuracy, of each detail, and the manner in which they are assembled together. It gives specifications of the materials from which the parts are made and prescribes how they are finished, both where they fit together and where they do not.

This department has contact with the selling departments, so that it may know and act upon the tendency of demand, and the foresight and imagination with which it works will decide whether the concern leads and originates the demand for its products, is abreast of, or follows the demand, since this department will be responsible for the first stages in the development of new or modified products. It must have two-way contacts with the sections for the design of plant and tools, and for the design of methods and processes, and with the production and inspection departments, so that it may be cognisant of the difficulties of manufacture, and in turn furnish to them the information they need for their work.

(b) Plant, Tools, and Means of Production.—It will depend on the nature of the product whether this section is necessary or not, and if it is necessary, what its work is. It may be that all the machinery and tools will be standard, and then “design” resolves itself into selection, and the duty may be shared between the production department and the purchasing agent, with the inspector holding a watching brief. At the other extreme will be a highly specialised product where it is better for the company to design, and perhaps build, its own machines and tools.

(c) Methods and Processes.—This section will decide how the product is made and which kind of machines are used, and will lay down the processes, and analyse them into operations, furnishing specifications, instructions, and perhaps times for production.

The three sections mentioned above will be very closely connected with one another—in fact, often they will be three parts of one department. They will have standard sizes and shapes or forms for drawings, will keep files of all original drawings, together with records showing how many copies have been issued and to whom. When drawings are changed, all issued copies should be withdrawn and the changed replacements issued.

(2) PLANNING

In laying out the processes of manufacture, the designer can estimate with considerable accuracy the time (actual working time) each operation or process takes; but this is not sufficient

either for estimating the capacity of the plant or for planning the work. There are few machines that work continuously without interruptions for re-setting, adjusting, lubricating, changing work pieces, and occasional breakdowns, and a more or less accurate knowledge of these is necessary. This knowledge is obtained by observation of the machine under working conditions for a sufficient period to obtain the average capacity. This information, measured and tabulated for every operation on every machine, serves two purposes. It enables the plant to be balanced—that is, so adjusted that each part of it is working at the same rate in terms of finished product—and it enables the planning section to lay out the work in advance, to know how long a time will be occupied in executing all the orders in hand, to say when a particular order will be ready for delivery, and to indicate to the selling department what promise may be made for delivery to a potential customer, with reasonable certainty that the promise will be kept.

This department must find out from the purchasing department when materials required from outside can be expected with certainty, and from the designing and tool-making departments when the tools will be ready. Usually there will be stocks of work in progress between processes, and perhaps stocks of finished parts, both in order to maintain the balance of production in case of unavoidable interruption of some process and in order to permit of inter-operation inspection. The planning department will decide on the necessary size of such stocks and will know at any moment the actual size and location of the stocks; in general, the capacity of the plant will increase slightly as the final operations are approached, so that there may be no congestion. For example, in a plant for making steel sleepers from flat or troughed sections, in three pressing operations, the capacity rates are 16, 17 and 18 per minute, in the first, second and third operations respectively.

The planning department therefore plays a most important part in manufacture—that of making orderly, balanced, and systematic production possible—and it controls as to time, but it also controls and reduces to the smallest dimensions possible the amount of capital locked up in stocks and work in progress.

It receives the customers' orders from the selling department, translates them into factory language, and re-issues them

as works orders to the purchasing, stores, production, inspection, packing, shipping, and invoicing departments, and advises the selling office of any untoward happening that may delay delivery, so that the selling office may, in turn, advise the customer.

(3) PRODUCTION

The production departments comprise the manufacturing staff, the maintenance staff, and the workshops, machinery, tools, etc., that constitute the plant, as well as the auxiliaries for light, heat, power, internal transport, and traffic and other services; also the works labour office, which is concerned with the engagement and dismissal of workpeople, and with the time-keeping and computation therefrom of wages, and usually also with the provision of watchmen and police at the factory gates.

(4) INSPECTION AND TESTING

There are several different ways in which inspection can be regarded, depending somewhat on the character of the product manufactured, and the reputation the company desires to maintain amongst those who use its products, as well as on the character and general atmosphere of the particular organisation under consideration. But in any case the department must be strong and capable of making its decisions respected as well as accepted. In many cases inspection will commence with the raw materials received; follow each operation and process, so that further work shall not be done on material or parts already spoiled; and end with inspection of the final product before it leaves the factory. Properly conceived, inspection is not a hindrance or bar to efficient and economic production, though it is often so regarded, but a very valuable aid, reducing the amount of work and material spoiled in all cases, as well as safeguarding the quality of the product ultimately delivered. The inspection department must, where accuracy and quality are very important, be capable of criticising not only product, but also processes, machines, tools, appliances, and even operatives. It must see that the standards both of accuracy and finish that it sets, or that are set for it, can be reasonably obtained from

the machines and appliances available, must reject and take possession of work that is inaccurate or of insufficiently good finish, and make strong representation to the competent authority whenever a tendency towards deterioration is found. The inspection department is really the conscience of the concern, and, like a good conscience, is ever wakeful and vocal when necessary. Although its special duty is the maintenance of quality, its existence is only justified by the fact that the department contributes to the quantity and low cost of production, and its criticisms, therefore, must always be just, reasonable, and constructive.

Continuous and large quantity production can only be carried on successfully and economically in the presence of a watchful, thoroughly competent and independent inspection staff.

II. COMMERCE AND ADMINISTRATION

That part of the organisation that has been referred to broadly as "commercial" also embraces several different kinds of activities, and can again be divided into groups as follows :—

- (1) Commerce.
- (2) Accountancy.
- (3) General Administration.

The *Commerce* group comprises :—

- (a) Selling.
- (b) Packing and Delivery.
- (c) Buying.

(1) COMMERCE

(a) **Selling.**—A complete selling organisation may be quite a complex unit, involving the study, analysis, and evaluation, as far as possible, of the various markets, home and export, and the means of exploiting them thoroughly.

The first analysis and evaluation of markets begins with the study of trade lists, directories, and such statistics as are available, and results in the preparation of lists of potential customers, which are checked, added to, or purified by subsequent experience, and by the reports of agents, travellers, and salesmen. Ultimately these lists or indices will contain all that it is necessary for the Selling Office to know—name of

customer, address, name of buyer or person to be cultivated possible or probable consumption or purchase of products per annum, and particulars of any special characteristic or peculiarity that it is desirable to know, so that orders may be obtained in the first place, and such service may be offered subsequently as will retain the custom once it has been secured.

These indices will, collectively, give the Sales Manager the material on which he can base his plan of campaign for the exploitation of each particular market.

The second function of the selling staff requires means for converting potential customers into actual customers, and the methods employed in order of directness and also of costliness per individual reached are press advertising, circularising (by post), and personal solicitation. It will depend on the character of the goods to be sold, on the number of potential customers, and on their accessibility, in what proportion, and in what manner, these three methods are used. Assuming that the product is of wide utility, and the list of potential customers (whether actual consumers or purchasers for re-sale) a very long one, advertising, more or less widespread in periodicals or perhaps daily papers, will be resorted to first. This will bring a certain response in the form of inquiries, either for quotations or for further information, and these inquiries, indicating as they do a more or less definite prospect of sales, will be replied to by letter, and perhaps followed by a personal call.

This advertising may be followed by a circular letter, or by the despatch to selected lists of potential purchasers of literature describing the product to be sold; if the total number of potential customers is relatively small, this may be the first step in the campaign, and possibly individual letters instead of printed matter or duplicated letters may be used. The primary purpose of both these methods is to attract the attention and arouse the interest of potential customers, and to draw something from them in the way of a reply or an inquiry.

As far as they can be traced, records should be kept of the response to each effort, and the style of the advertisement should be modified according to the amount of success achieved.

This identification of an inquiry with the effort that produced it is often very uncertain and difficult, but usually some general indications at least can be obtained.

Except in the case of an article of widespread demand when sales can be made direct to the public, or in a case where, though the number of potential customers for an article is relatively small, the chance of making sales is good, personal solicitation is used cautiously, and the path of the caller is prepared, as far as possible, by previous correspondence, so that a costly expedient may not be used wastefully, and also in order that the dignity of the company selling may not suffer. The "dignity" of a manufacturing company that must sell its product is still quite a real thing, and often mentioned in discussions on sales promotion, though not to the extent that it used to be.

All that has been said on this subject up to now relates to the "home" or "head" office, but in many cases branch selling offices or agencies are necessary to cover adequately even the home territory, and more so to exploit overseas territory, with any pretence to thoroughness.

The choice as between travellers or salesmen from "home" and branch offices will depend on the need, or absence of need, for the representatives to have a close knowledge of, and to be intimately identified with, the locality they are set to work.

The choice as between branch offices and agencies depends on the amount of control required, and the length the company is prepared to go in finance. The range is from an agency that finances itself, and is paid simply by commission on sales, or that purchases outright to sell again, to a branch office which is under complete control and of course is financed completely.

The same considerations apply exactly in overseas territory, except that usually in this case there must be a local representative, either an agent or a member of the company's staff.

It should be remembered that the indices referred to earlier constitute the Sales Intelligence, and must be kept complete, alive and up to date, and in order that this may be done, reports should be made of each contact with a customer actual or potential, whether the result of a personal call or merely of a telephone conversation.

(b) **Packing and Delivery.**—This section will receive the goods from the production departments, together with the inspector's certificate that they have been found satisfactory and ready for despatch. It will previously have been warned, and have been given packing and delivery instructions by the planning section. It will, in turn, notify the invoice section of the despatch, giving any relevant particulars, such as the number of packages and list of contents of each, and the shipping marks, etc.

In the case of certain branded goods or proprietary articles for which a standard form of package is used that forms part of the article or goods, the packing is one of the production processes; the actual despatch, however, and, in some cases, the further packing in cases, conforms to the usual plan.

(c) **Buying.**—In general, the buying for a manufacturing organisation should be done from one centre. It enables better prices to be obtained, saves clerical work, and is more orderly, more satisfactory, and less liable to abuse of any kind than when it is done from two or more centres. In cases where purchases of raw materials form a very large part of the cost of the operations, this part of the purchasing may be and often is separated from the remainder, and becomes the duty of one of the principals.

The chief danger of concentrating the purchase of all requirements, materials, fuel, stores, tools and machinery in the hands of one man, who cannot himself have expert knowledge of all these things, and must always buy from those who have, is that he may make lowness of price the only criterion. The safeguard against this tendency is to have each article or material fully and authoritatively specified as to analysis, properties, or other important qualities, and inspected on arrival by the regular inspection staff to ensure compliance with the specifications.

Unlike other activities, the code of rules for the making of purchases should be rigid, and their observance should be as formal as is reasonably possible.

(2) ACCOUNTANCY

In these departments or sections are collected all the activities concerned directly or indirectly with money and its

control; in the cashier's office is centred the whole of the monetary transactions between the company and the outside world; the wages office controls the book-keeping as regards wages and salaries; the internal book-keeping concerned with materials and goods in different conditions is known as stores control; the invoice section deals with all invoices, whether inwards from suppliers to the company, or outwards to customers. The three sections last mentioned furnish the basic figures for the three that follow—namely, the department responsible for keeping the “books” of the company, and for the preparation of the profit and loss account and the balance sheet from the accounts in these books; the cost department; and the statistical department.

This brief description shows the close connection that exists between the different parts of the accountancy group; and it may not be superfluous to point out that it will not be possible in practice, always and everywhere, to separate the activities in the different sections from one another as completely as might appear from Fig. 2, which is given as a general illustration, and not as a pattern or model suitable for copying. Further, it may be useful to mention some points for guidance in organising these departments, especially as a later chapter deals specifically with accountancy.

Wages.—The aim of the wages office is the calculation and collection, the combination and separation of the figures based on agreements with the workers. It is necessary to obtain a clear statement of the total sum paid for each wage period; of the sum for each shop or group of men working together; of the workers according to trade, sex, and age-class; of the amount retained for insurance or deducted for other purposes, etc. The different denominations of money must be determined so that the wage packets can be made up speedily and exactly; and a statement showing the earnings of each worker, and how the total is made up, should be prepared and handed to the worker before payment, or in the wage packet. Further, a continuous account ought to be kept for each worker, showing the payments made at any one time, and during any particular period, so that authoritative figures may be at hand in case of need.

If it is remembered that this enumeration is not at all

exhaustive, that it is imperative that the whole work should be finished within a predetermined time, and that care must be taken by special test methods to ensure that no mistakes are made, it will be clear that careful and accurate organisation of the wages office is abundantly necessary.

Stores Control.—The office for stores control keeps accounts for each kind of material used in the works, showing the changes in the quantity and value of each. The issues and receipts of each kind, as well as the balance in hand, must be clearly obtainable at any time, and care must be taken that the figures in the accounts agree with the actual stocks in the works. Differences, which cannot always be avoided, must be cleared up as soon as discovered, and the necessary corrections be made not only in the stores control accounts, but also in the book-keeping accounts.

Invoice Department.—In the invoice department it has to be decided whether filing is to be done according to the alphabetical order of the customer's or supplier's name, or according to subjects dealt with, or according to a combination of the two methods. Such decisions can only be made with a knowledge of the circumstances of the specific case.

Book-keeping, Costing, Statistics.—The accounts kept in this department must conform to the requirements and particular features of the business. They must be put together from the point of view of cost accounting and of production, as well as of the book-keeping itself. Production, in particular, requires assistance and stimulation from cost accounting in addition to control; and cost accounts that are designed only to produce cost information for control miss the accomplishment of their most important purpose. This is a real failure that occurs in practice, and to avoid it information about costs and statistics are required which call for understanding and co-operation from both costing and production departments.

The cost statistics for successive periods—weeks, months, or years—will show at once the tendencies of the business as regards costs, and any tendency other than a steady fall in costs should be brought to the attention of the appropriate authority for investigation and action. In order that continuity of comparison may be maintained over long periods, in spite of changes that may be made in the system of distribution

of cost, some factor should be found that will give the relation between the costs before and after the change.

The next and not less important use of costs is as a guide and aid to increased efficiency of production. This requires that the cost data should be indisputably correct and unquestionably accurate in tendency. That is, the data must be purified of all factors that are irrelevant to efficiency. For example, if a machine is idle for part of a period owing to lack of work, the standing charges for the time it is idle must be entered in a separate account, and not be allowed to falsify the cost of the lower quantity produced.

If the character of the work varies from time to time, the periods compared must be long enough to have embraced all variations and be of the same average composition.

The cost data must be rapidly and punctually available after the completion of the work, so that they may be reviewed while the circumstances are still fresh in mind.

Sufficient details should be furnished or available for making effective comparisons.

When statistics are furnished regularly and systematically, their utility and the use made of them should be challenged from time to time, and useless or obsolete data be eliminated.

It must be possible to have a general overall check of the costing against the company's accounts, and the profit and loss account.

(3) GENERAL ADMINISTRATION

This division includes legal business, company business, taxes and insurance, and other matters that fall within the duty of the Secretary. These need no further comment from the point of view of organisation, but some remarks may be made about the other features of general administration.

Selection of Personnel.—After all that has been said about leadership and kindred matters, it will be understood that this activity is to be taken very seriously and treated systematically. Hence it has become usual to include in the organisation of undertakings employing large numbers of people someone to take the preliminary steps in the selection and placing of employees, both staff and operative. Such a member of the staff can find and interview applicants for employment in a

preliminary way, obtain and record personal particulars, and broadly classify them ; and keep live files concerning applicants that will enable him to submit a list of people apparently suitable to be considered for any vacancy that may occur. If he is sufficiently experienced, and not too opinionated, he may advise as to the final choice.

It is safer and wiser, however, to confine his duties formally, at least, to primary stages. There is only one function more important than the selection of personnel, and that is the treatment of the personnel after selection. The only person who can properly discharge this function of selection, and has the right to discharge it, is the person who is going to direct, and be responsible for, those chosen. Human personality is infinitely various ; the humblest workman has individual characteristics, and is entitled to, and moreover will repay, all the individual treatment and consideration that can be given to him.

Few people will acknowledge any doubts as to their ability to judge other people, and some will boast that they can judge, classify, and docket anybody in the briefest of interviews. Judgment at such a pace is inevitably incomplete and often completely wrong. An employment manager, entrusted with unfettered discretion, may either select the wrong people or, from his own prejudices and predilections, restrict the material available for selection.

Another duty sometimes imposed on the occupant of this position is that of dealing with representatives of the trade unions, either on the general conditions of employment or in regard to particular grievances, either of individuals or of the whole body of employees. As in the case of the selection of employees, his discretion and authority in this direction also should be limited and safeguarded.

Welfare.—If the number of employees is sufficiently large, a supervisor may be appointed to do whatever he or she can to enhance the well-being and happiness of the whole body of employees. This is a somewhat delicate and difficult position to occupy satisfactorily, but the work, if well done, is of the utmost value to everybody concerned. If badly done, it may lead to complaints from the management that the workers are being “spoiled,” or from the workers of intrusion and improper interference with their private lives.

A wise and far-seeing employer once instructed his welfare supervisor "to be a good friend to every employee, young or old," and, perhaps, with that injunction the matter may be left.

Typewriting and Filing.—It is in this section of the general office that one is likely to find over-centralisation and over-organisation.

Machines for typewriting, calculating, book-keeping, addressing, and circularising; for opening, closing, and stamping letters; or special filing systems in standardised cabinets or racks, have been thoughtfully developed and brought to a high degree of utility and efficiency. They have been, and always will be, a valuable help in business, and they lighten and ease the routine work, some of it very intricate, which is inseparable from the services required of the offices of a manufacturing concern. It seems, indeed, that without all these auxiliaries modern business development would have been impossible.

It is a great calamity, however, if this whole apparatus and equipment for modern office work is allowed to dominate, instead of serve the organisation. One can understand, and to some extent sympathise with, the enthusiasm of an office manager, keenly interested in his work and desirous of reducing its costs and increasing its efficiency, who wishes to centralise everything, and is willing to subordinate everything else to this idea. The point that is missed, however, is that all these things are intended and required to *serve* the achievement of some other purpose, and are not ends in themselves. Office work is not done so that office work may be well and cheaply done, but as an auxiliary to the carrying out of some other process or purpose. The office manager is undoubtedly right to strive to carry out the work as efficiently and cheaply as possible; but he is just as undoubtedly wrong if he allows this aim to interfere with the quality, the value, and the convenience of the service he controls to those who need it. It is so fatally easy to waste the time and energy of, and to irritate and disturb, officials who have themselves intricate and important duties, upon the punctual and due performance of which hangs the efficiency of the undertaking.

Further, when considering the organisation of office work, it must be remembered that it calls for a combination

of mental and physical qualities, and psychological factors are therefore of much greater importance than in purely mechanical work; neglect of or clumsy dealing with these factors will not only reduce efficiency, but may so affect the quality of the service as to make it useless.

A certain amount of centralisation is useful, and necessary, and adds to efficiency, and the splendid development of office equipment has made it possible, but care must be taken not to carry this centralisation too far.

COMMENTS ON THE ABOVE OUTLINE

We have now seen in broad outline the character of the duties or functions that have to be performed in some measure in every industrial organisation, and the relations between those that perform them; but the exact importance of these functions, and the relative standing in the business of those discharging them, can only be defined in relation to a particular undertaking. For example, design of product, in the case of a gas company, a water company, an electricity undertaking, or of many chemical and metallurgical companies, is dictated at the outset by circumstances; and design of plant and process, much more important and difficult, is also settled before operations begin, and, once settled, is seldom changed. In engineering manufacture, however, design of product as well as design of plant and processes continues as long as manufacture, and any neglect of these duties usually determines, sooner or later, the life of the undertaking.

Planning of work in a continuous manufacture such as, for example, sulphuric acid, coke, or gas resolves itself largely into the provision, at the right time and place, of the necessary raw materials, and is therefore comparatively simple; but in batch manufacture of a speciality, planning is important and complicated, and much more so when several specialities, or even several products, are manufactured in the same plant.

Inspection, in the manufacture of a standard and simple product, may be relatively easy and unimportant; but in the manufacture of the same article or product in higher qualities the importance of inspection is much increased, and in a few cases may be paramount.

Sales organisation and development is necessary (a) where there is competition, (b) where it is desired to increase demand, (c) where the product is entirely new and markets have to be created.

And so returning to the starting point, it must be emphasised that the organisation must be designed and built to suit its particular purpose, and modified as the needs of that purpose change, either from internal causes, or because of changes in markets, in demand, or other external circumstances.

TYPES OF ORGANISATION

The type of organisation referred to above has been called the "line" or "military" type of organisation, probably because the prevailing feature is discipline, and the control of some workers by others of higher rank. F. W. Taylor, the originator of "Scientific Management," proposed what he called "functional" organisation, in which a body of workers would be controlled as to the different features of their work by different foremen, called functional foremen, such foremen being specialists in the particular function they control. Whilst these proposals have undoubtedly influenced thought, and the form and type of organisation to some extent, they have probably never been completely adopted, and the reason is not far to seek. Specialists are always in danger of becoming very narrow in their outlook, and it is not difficult to imagine, say, three specialist functional foremen, each thinking exclusively of his own function, issuing to the same body of men contrary, or at any rate inconsistent, instructions with regard to their work.

These proposals really aim at carrying the principle of the division of labour to its logical conclusion, and if used with moderation and a sense of proportion the division of labour is undoubtedly sound and economically necessary; but it is never wise, even if possible, in any decision involving human beings, to carry proposals or principles to their so-called logical conclusions.

COMMITTEES : THEIR USES AND LIMITATIONS

Another development of modern management is the setting up of committees, a useful development provided the limita-

tions of committees are kept clearly in mind and they are not allowed to waste too much time in debate. A committee cannot control anything; on the contrary, it needs to be controlled. A committee can rarely decide anything except by voting, and where is the manager who will be willing to accept responsibility for, or put into effect, "decisions" arrived at by a chance majority of his subordinates, or even of his colleagues? Since a committee cannot do anything, it cannot therefore have executive authority, but should be only a consultant body.

Nevertheless, because discussions bring out differing views and opinions, committees may be of great value to a manager who knows how to handle them. Even if a committee's decisions do no more than confirm his own decisions already made, they give him confidence, either from the absence of weighty arguments against his own decisions, or by the opportunity given him of hearing, analysing, and evaluating such opposing arguments as have been offered.

CREATING A NEW AND IMPROVING AN EXISTING ORGANISATION

Much, very much, has been written on organisation, and there is a considerable literature on the subject in many languages.

Many ingenious systems have been devised and appliances invented to facilitate and to render the work of management of office and workshop more or less mechanical and automatic. Some of them are good, but the value derived from them depends on how they are chosen and used, and whether they suit or do not suit the people they affect.

Let us repeat emphatically that management or organisation is not a science, and cannot be mechanised or standardised; still less can it be made automatic. It is a human function, and the exercise of it is a human attribute.

It is for this reason, that, if the need arises either to create a new organisation for a particular business or to improve an existing organisation, it is impossible to find, either in the specialised literature on the subject, or by examining the organisations of other businesses, any cut-and-dried solution of the problem, or any system that can be safely copied and

applied to circumstances other than those for which they were designed.

How can it be otherwise when every business takes something of its character from its founder, its present leader, the chief members of its staff, and even from the character of its workpeople, and in consequence is different in some respects from every other business? Moreover, it is usually very desirable, if not necessary, to preserve this individuality and the tradition of the concern. It is neither possible nor wise, if it were possible, to standardise human beings; to suppress their individual characteristics, and force them to conform to, or fit into, a particular system, however ingenious or attractive.

What, then, is the solution of the practical problems of creating an organisation for a proposed new business, or of improving an existing organisation? The latter is an ever-present question, and may therefore be considered first. It is assumed that every important member of the staff is known intimately by the one who is going to carry out the work, and that he trusts, and is trusted by, them. If this is not true, clearly the first step, and a vitally necessary step, is to make it true. The next thing is to discover, by patient and persistent inquiry and observation, what and where are the weak points; where waste and loss occur; where there is material congestion, or overwork, or lack of direction, or control; what are the weak points of the staff; what the troubles they are unable to cope with satisfactorily; the source of the friction, disagreement, or incompatibility. Then, in consultation with key men, means must be devised for building up and strengthening at the weak points, stopping all the leaks, giving to each change time sufficient to its thorough testing and assimilation before proceeding to the next. This may mean some additional staff, or only a rearrangement of duties, but the course of research suggested will not only reveal the troubles, but also indicate the solutions.

In the case of a new organisation, the answer is somewhat similar, and has been given earlier in these pages. It is to appoint at first only a nucleus or skeleton staff, and add to it as the necessity becomes obvious and imperative. To avoid, if possible, large increases of staff at one time, only one or two men should be engaged at a time, and then an

interval be allowed for them to get bedded into their places, and to become assimilated in the organisation.

In both cases great and sudden changes should be avoided, and, even after relatively small changes, a short interval should be allowed for "the dust to settle." On the other hand, these intervals should not be allowed to last long enough to produce stagnation; there must be perpetual progress, but not necessarily perpetual motion.

CONCLUSION

Yet once more, in organising, in devising, adding to, or improving an organisation, the primary, fundamental, and essential factors are the character, temperament, and temper of the people who control and are controlled by it; and the more complete the knowledge of, the sympathy with, and the appreciation of the human qualities of the controlled by the controllers the greater will be the success achieved. And since human genius and effort are almost unlimited, so too are the possibilities of success. Rules, principles, systems—all these can aid, can to an extent relieve, can supplement, and so be made to serve, but they can never be substitutes for the exercise of that justice and sympathy between man and man on which all success depends. The only control that is real and effective is self-control. The best manager or leader is the one who, appreciating this fact, so comports himself towards his people as to bring out and develop their best qualities and the highest traits in their characters.

In the preceding pages the importance of what has been called the "human factor" has been stressed and re-stressed again and again. There are many repetitions, and no apology is offered for them. It has all been quite deliberate.

Technical difficulties are easily overcome, and technical processes or appliances rarely fail finally, but are successfully dealt with by the persistent application of well-known methods. The problem of successfully directing human beings is more difficult, but its solution, indicated in this book, is as old as the human race. No informed and worthy book has been written, or speech, sermon, or lecture delivered on the social or industrial relationship of mankind that has not emphasised the basic

principles mentioned above. And yet, in a long experience of industrial management in three different countries, and among men of many nationalities, the authors have seen more waste, more loss, ranging from stark failure to limited and mediocre success, caused either by ignoring, apparently wilfully, the existence of this age-old problem, or by the rejection of the equally old and well-known method of solution, than from all other causes together ; and the resulting loss of human happiness adds up to an appalling total. To write of industrial management and organisation without insisting on this aspect of it, even *ad nauseam*, is impossible.

CHAPTER III

WORK AND TIME STUDIES

ON an earlier page, reference was made to the importance of the element "time" to the clear knowledge and measurement of labour, and it is now proposed to describe the research that is usually known as time and motion study, which is the principal method of examination of work in detail.

It must first be stated, however, that this term, time and motion study, while convenient, is not in some respects quite happy. The word "motion" really has a very narrow meaning, because it is used to designate the smallest measurable action of a worker in carrying out production or manufacture; it is therefore better to use the more comprehensive word "work" for the present purpose, which has to deal with all the actions of hand or machine, either with or without the use of tools, devices, jigs or fixtures, gauges, instruments, or other equipment, including the design, arrangement, and manufacture of these appliances, since it is not wise to limit the investigation to the work finally executed.

Then again, before the time element can be dealt with, the work as defined above must be examined in minute detail, and it is therefore intended to change the sequence here and speak of the research as work and time studies; it is always desirable to deal with the matter on the broadest possible basis, in order that in any particular case the whole truth is laid bare, and the best and most complete results are obtained.

The method of carrying out such studies can best be explained in reference to illustrations and examples taken from practice, but before this is done it is necessary to explain the definitions and terms that have been found useful.

There are many ways of analysing work and time observations, but it is proposed to give one only, which has been selected as the result of experience and has been tested in

different branches of industry. It may therefore be recommended for general use, perhaps with modifications to suit special or specific cases; but subject to the proviso that consideration must always be given to the question as to how far the inquiry may be profitably pushed in any given case.

ANALYSIS OF WORK

We have seen that the works order—that is, the document authorising the execution of work in the factory—results from the translation of the customer's order into the language of the factory or works.

In the course of this translation some customers' orders may be combined in one works order, or one customer's order may be embodied in one or more works orders, according to their extent—that is, according as they refer to one or more separate products, and the works orders are arranged either according to the nature or to the sequence of the work; in other words, they conform to the *production plan* which is built up from product, production groups, or assemblies (main and sub-groups) and jobs, and to the *working plans* of the different jobs, built up from processes, operations, motions, and units of motions.

A *Process* is a complete series of operations for the purpose of production, performed by one worker, or a group of workers co-operating, at one working place.

An *Operation* is the next smaller unit, or a stage in a process of production, carried out at one working place.

A *Motion* is a compound group of actions of the worker in the course of production, or preparation for production, consisting of several units of motion. Sometimes, several motions may be treated as one motion for simplification of calculation, and this is called a *motion group*.

A *Unit of Motion* is the smallest observable or measurable action of a worker in the course of production or preparation of production, consisting of a single complete movement.

It will be apparent that motions and units of motions referred to in these explanations are those of workers, and not those of machines. The other terms defined can be used equally well for machine as for hand work.

A clearer understanding of the meaning of all the terms mentioned above will be obtained from an examination of the practical example shown in Fig. 3 and the following brief explanation of it.

The production plan concerns the manufacture of a complete electric motor, and the working plan only one part—the motor shaft. For each part mentioned in the production plan a working plan must be developed. For the assembly of separate parts into production groups or assemblies, a working plan must also be developed, as well as for the assembly of the groups into the complete or finished product, and for such other jobs as testing, painting, packing, etc. These are not shown in Fig. 3 on account of lack of space. The points at which these supplementary plans begin are indicated by crosses (x).

This example of a motor shaft was taken from the works of a firm that had been manufacturing such shafts in large quantities for many years, and where it was believed that the cost of production had been reduced to a minimum before this method of analysis was adopted. It is interesting to note that, contrary to expectation, it was found possible to reduce the cost of direct wages by about 40 per cent. of the former cost, whilst raising, at the same time, the wage-earnings by something between 10 and 15 per cent.; obviously this result was achieved by making small changes in machines and tools and their use, and in the sequence of the separate operations or motions, and finally by organisation and better control of the work.

On the other hand, it is evident that this method of analysis and study furnishes a possibility of, and perhaps in some cases a temptation to, abuse, and it is thought advisable right here to sound a warning. It is quite essential to success that the willing and whole-hearted co-operation of the worker should be obtained, both in the course of the study and afterwards in putting into force the changed practice, even where it concerns the use of any new tools or appliances that may be decided upon. If the worker co-operates in the work, he is entitled in equity to share in the results, and if, therefore, there is a resultant reduction in cost, there must be an increase in the worker's wage, and the price of the work must be so fixed as to permit of this.

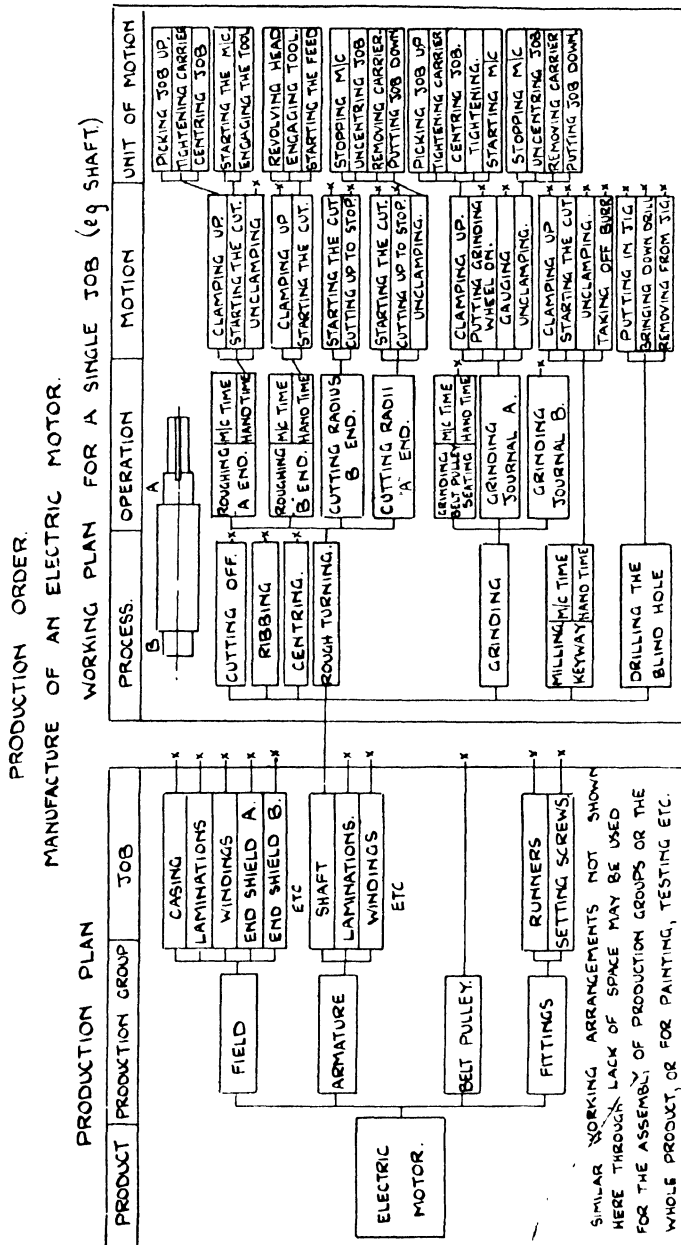


FIG 3 FORMATION OF PRODUCTION PLAN AND WORKING PLAN TAKEN FROM MACHINE SHOPS.

Moreover, working under the new method may impose a greater strain on the worker than the old method, not because the work is harder or more difficult (this is very rarely, if ever, the case), but because he is kept more fully occupied. Unless this is recognised and provided against, fatigue may result, and the cost be raised instead of lowered. It is not wise, therefore, to endeavour to obtain the last ounce of effort from the worker; and any attempt to exploit him in the direction of extracting a greater result for the same wages will assuredly and deservedly fail.

Two additional examples, taken from other industries, throw further light on this kind of analysis and study, and need no further explanation. They are shown in Figs. 4 and 5.

TIME ANALYSIS

It is hardly necessary to explain that the time referred to here is the time available for the purpose of industrial production, consisting of the working periods or shift time, and excludes leisure time, Sundays, usually holidays, and all the hours—or days—during which work is not possible on account of lack of orders, breakdowns, labour disputes, etc.

Shift Time.—According to the kind of work that is being carried out, and the purpose for which it is being analysed, shift time can be considered from three points of view : (1) that of the worker, (2) that of the equipment, machines, furnaces, tools, buildings, etc., and (3) that of the material or work pieces.

The workman works by hand, which is guided by the brain, consciously or unconsciously, or he supervises the work of a machine, or he stands by to intervene when it becomes necessary.

The equipment is in use or it is idle; if in use, it either produces or is being set up or adjusted; if idle, repairs may be taking place, or it is being maintained, or is out of service altogether.

Material or work pieces are either being treated or worked on, or waiting between treatments, or processes, or operations, or being transported. All these times are regarded as active time; the idle time is the time during which production has ceased.

PRODUCTION ORDER.
MANUFACTURE OF A WIRELESS CABINET.

WORKING PLAN FOR A SINGLE JOB
(e.g. TOP OF FRAME WORK OF A WIRELESS CABINET.)

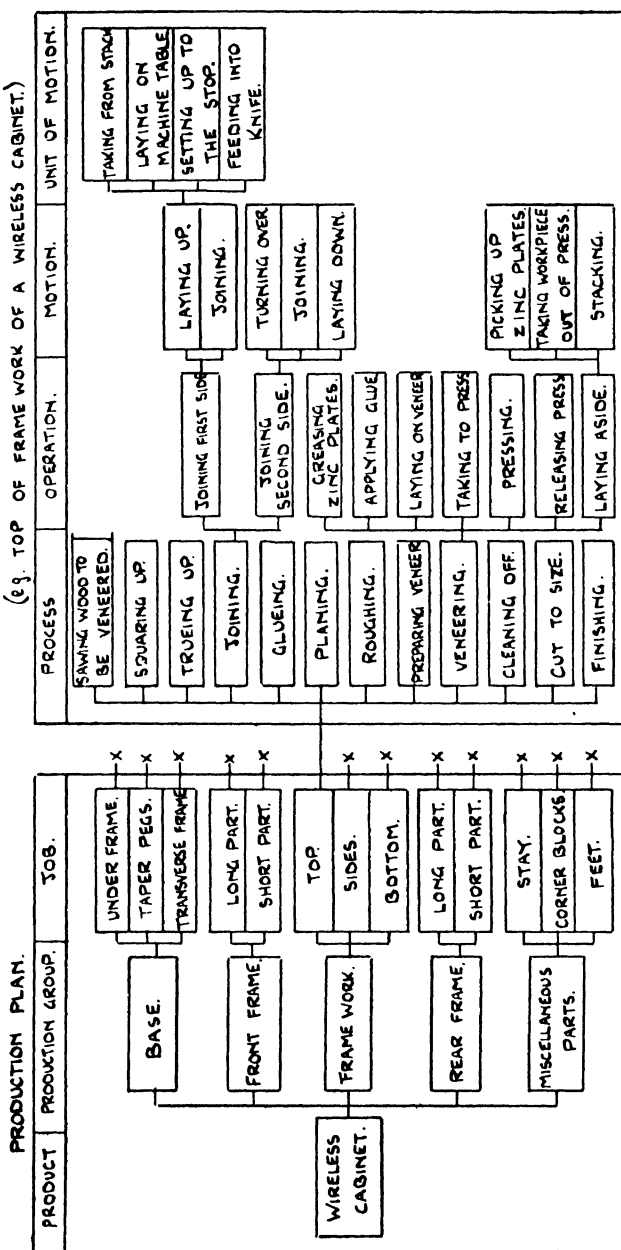
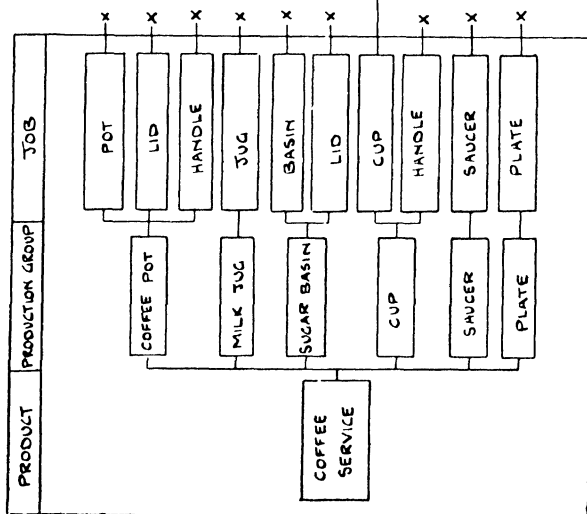


FIG 4. FORMATION OF PRODUCTION PLAN AND WORKING PLAN TAKEN FROM WOOD-WORKING INDUSTRY.

PRODUCTION ORDER
MANUFACTURE OF A COFFEE SERVICE

PRODUCTION PLAN



WORKING PLAN FOR A SINGLE JOB (eg. CUP OF COFFEE SERVICE.)

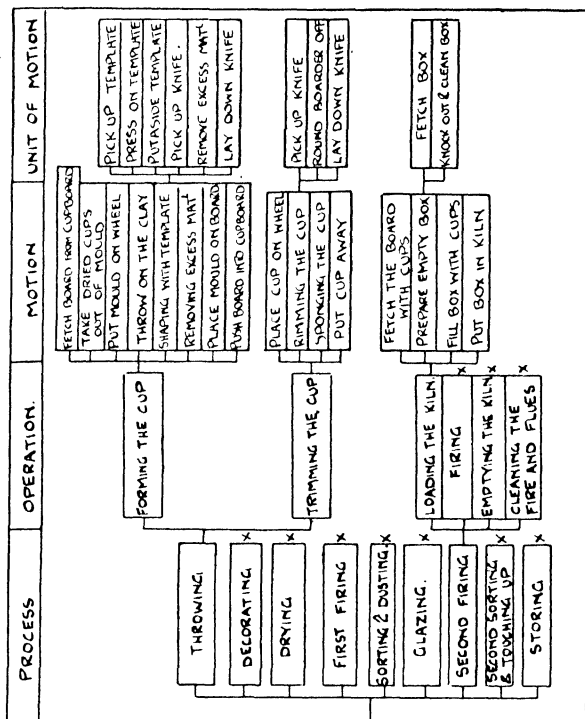


FIG 5 FORMATION OF PRODUCTION PLAN AND WORKING PLAN TAKEN FROM POTTERY INDUSTRY

This analysis of shift time is further explained and illustrated by the diagram Fig. 6. It must be noted that this diagram is merely to show the existence of the several divisions of time, and has no other significance; these divisions may vary in magnitude, in relation to one another, and even may not be co-existent. When it is desired to show their relative positions on the clock and their magnitude or duration, they are usually set out to some convenient scale, with one significant dimension only—length, as shown in Fig. 7.

This type of time diagram or chart has proved of great convenience, and is much used; such diagrams may be combined or superimposed, as is done in Fig. 7 (which may be called a “production diagram”) to show the relation between conditions of men and plant, men and material, or plant and material, and will be used for such work throughout this treatise.

Working Time.—It is now necessary to examine further what has been called working time proper. This is the most important part of the shift time, and its length is measured or determined for many purposes; planning of work, forecasting of delivery date, calculating the price to be quoted, fixing piece-work prices for workmen, etc., all require that the working time and its ratio to shift time shall be known with accuracy that depends on which of these purposes it is to be used for. Moreover, it must be analysed further, as will become apparent later, for the purpose of “rationalising” the process—that is, eliminating any motion or work that can be dispensed with, and thus reducing the cost.

Assume that it is required to determine how long it takes to do a particular job, to carry out a process on a batch of parts, or material. Before the work of production proper can be commenced, the work place must be got ready, the tools collected, or the machine set up or adjusted. The time taken for this may be called setting-up time or adjustment time, and it occurs only once for each lot or batch passed through the process in the same production plan, and must be added to the time afterwards determined. Then the production time can be represented by one or other of the sections of Fig. 8 (8a, 8b, etc.).

The first piece is processed (8a), then the second, and so on,

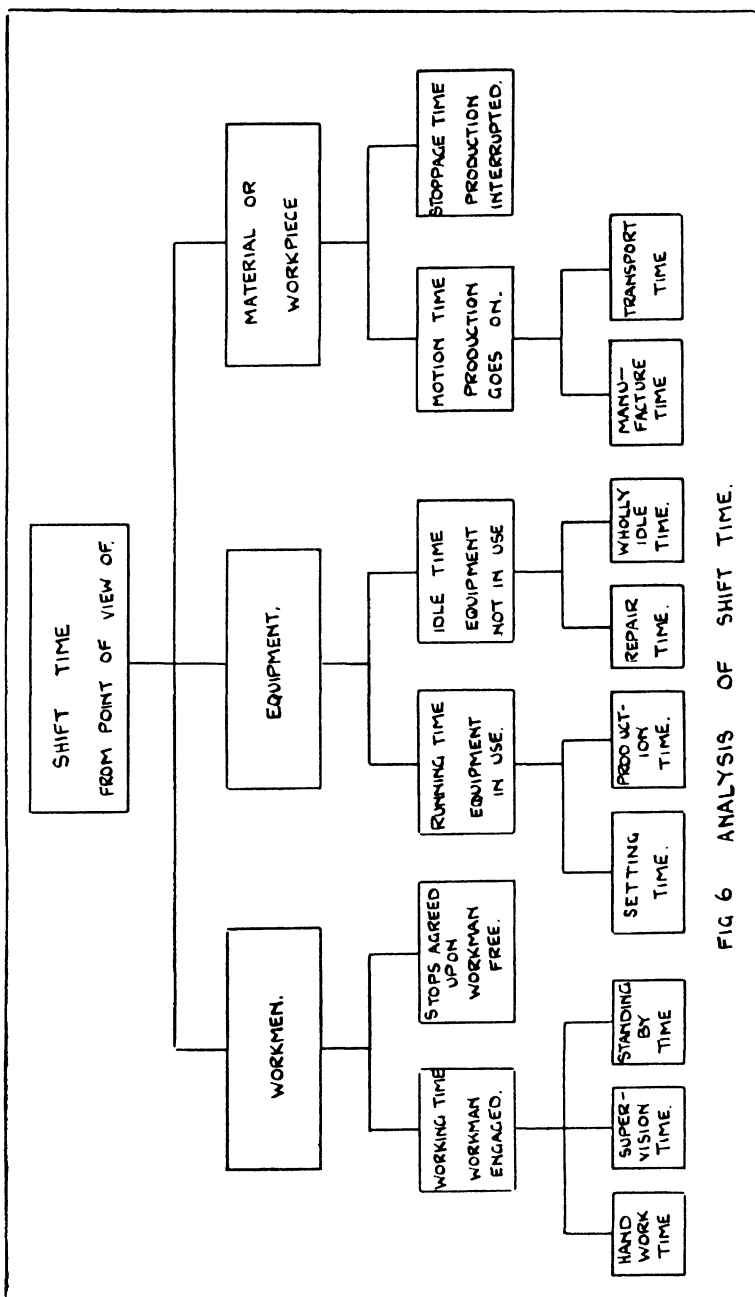


FIG 6 ANALYSIS OF SHIFT TIME.

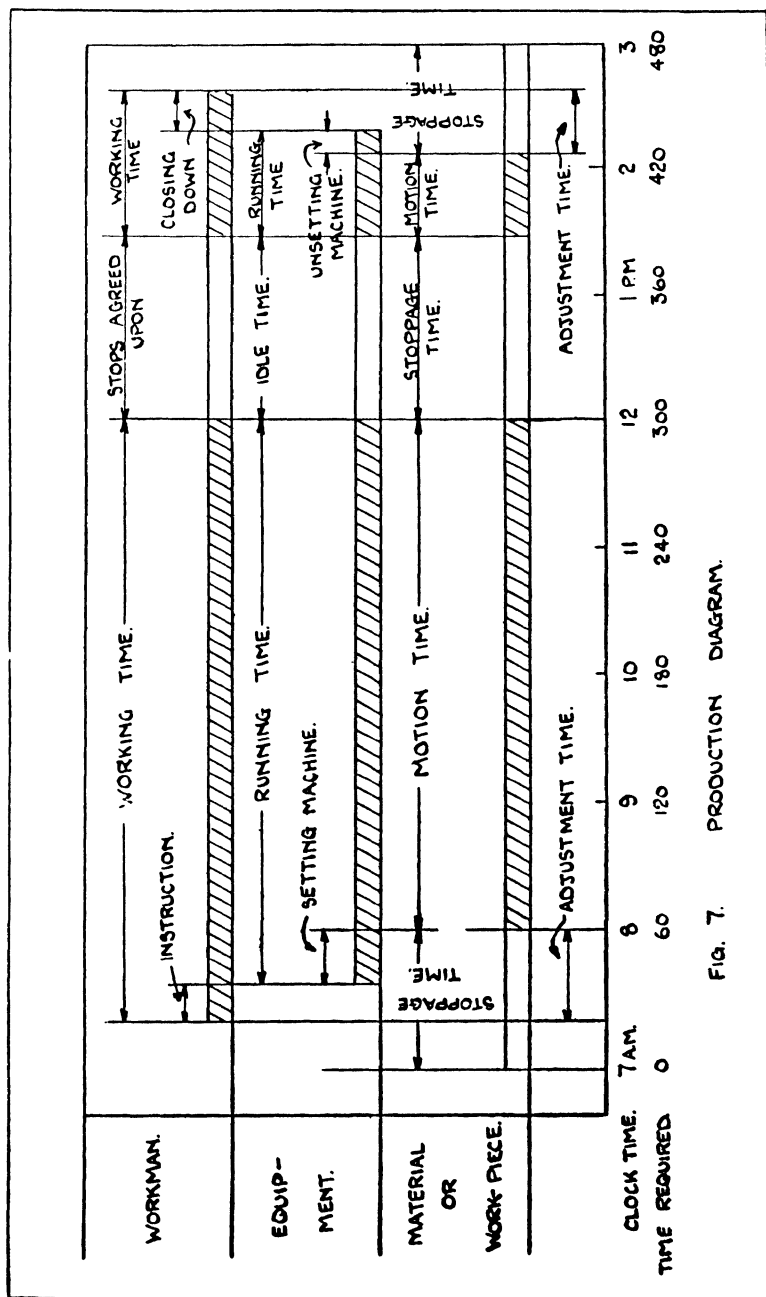


FIG. 7. PRODUCTION DIAGRAM.

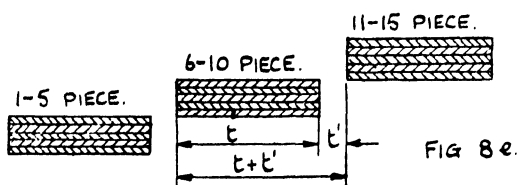
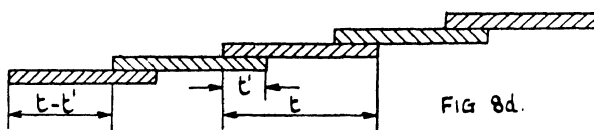
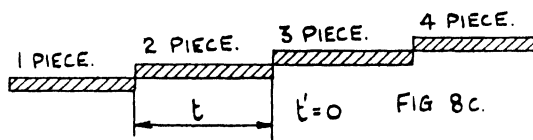
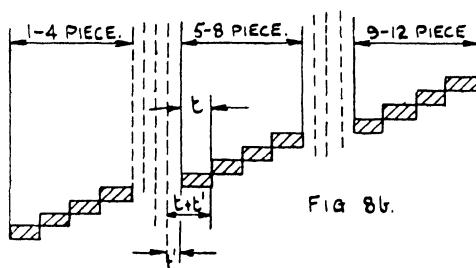
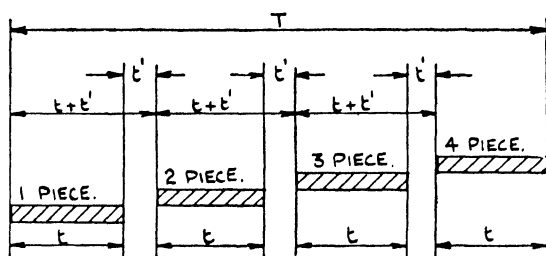


FIG. 8. SHOWING CONNECTION BETWEEN BASIS TIME, INTERMEDIATE TIME, AND PIECE SEQUENCE BASIS TIME.

but there may be, as here shown, an unavoidable interval after the completion of one piece and before the commencement of the next. This interval (measured on the chart by the length of the gaps) may be called intermediate time, and the time for the process on each piece except the last is the sum of these two times, process time and intermediate or gap time; then the total time for the batch is the sum of all the process times, plus the sum of all the gap times.

If T = total time, t = process time, t' = intermediate time, and n = the number of pieces in the series, then:—

$$\begin{aligned} T &= (n - 1) \times (t + t') + t \\ \text{or} \qquad &= nt + (n - 1)t'. \end{aligned}$$

If the gap time is relatively short and the number in the series relatively large, the total time will, with sufficient accuracy, be the sum of process time and gap time, multiplied by the number in the series. An example of such a series would be the rolling of a number of ingots into blooms.

Sometimes this interval occurs, not after each piece, but only after a constant number of pieces, as shown in 8*b*. For example, the blooms referred to above may be rolled down in the same mill into billets, and the billets afterwards cut into lengths. Then the time and order shown in the chart would be the time and order in which the billets are cut, and the total time would be as before, if we are referring to the multiple lengths of billets.

It is possible that the intermediate time may be so short that it is negligible (8*c*). In this case the total time for the series will be found by multiplying the process time by the number of pieces. $T = nt$, since $t' = 0$.

Work may even be commenced on each piece before the preceding piece is finished, as in 8*d*. In this case the total time for the series is the sum of the process times less the sum of the intermediate times, and is shown by the equation:—

$$\begin{aligned} T &= (n - 1) \times (t - t') + t \\ \text{or} \qquad &= nt - (n - 1)t'. \end{aligned}$$

If a constant number of pieces are treated simultaneously, instead of each piece singly, the conditions are represented by

8e. An example of this might be the drilling of holes in a batch of plates stacked one above another.

There are other possibilities, but this is sufficient for the moment.

The general form of the equation given above is therefore :—

$$T = nt \pm (n - 1) t'.$$

It must be remembered, however, that to the time so found must be added the time necessary for adjustment or setting up. Further—for this is not the whole story—there are other allowances to be made, the overlooking of which will cause considerable trouble amongst workers, whether the study is being used for the determination of payments by results, or for the judgment and comparison of results. In fact, in the early days of the application of time-study methods the mistake was rather naturally made of overlooking the necessity for these allowances, and considerable dissatisfaction with and distrust of the method did actually arise, and is probably not even yet altogether dissipated.

In the execution of any piece of work, delays almost inevitably occur, sometimes as the result of human fallibility, and sometimes caused by faults in the equipment and organisation. Obviously it is, and must be, the aim of managements to reduce these to a minimum—and this is one of the purposes of work and time studies—but until perfection is reached they must be allowed for in evaluating the performance of workers. Therefore the times calculated by the methods indicated above must be increased by the addition of allowances for lost or wasted time, or delays from causes not under the control of the worker, and this is usually done by means of a percentage. The percentage may be estimated, found by trial and error (although this is not usually satisfactory), or measured over a long period, or in a large number of cases, and the average taken.

Even in setting up or adjustment, this allowance is necessary ; and so to the adjustment or setting-up time, which may be called the adjustment basis time, an allowance is added which can be called adjustment lost time, or simply delay, to obtain the total time for adjustment. And to the process time or piece sequence basis time is added the allowance for delays

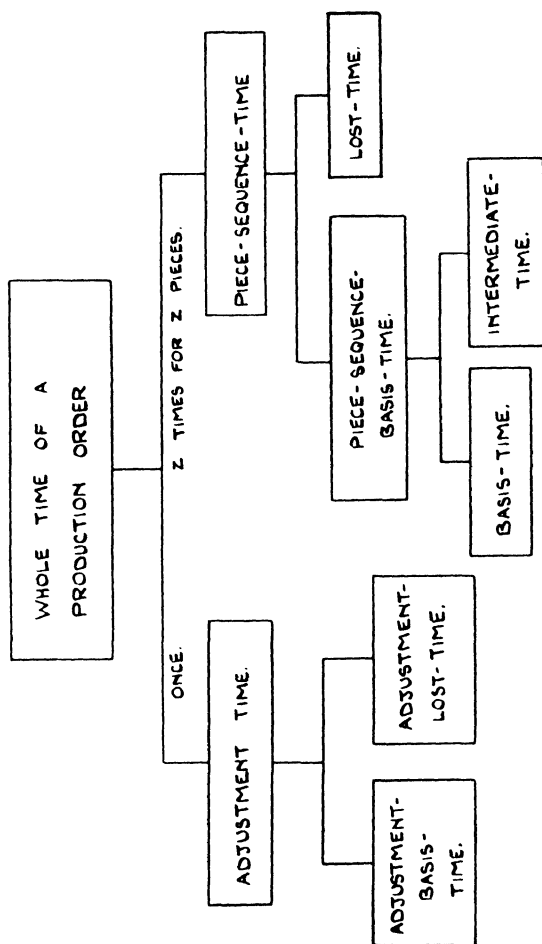


FIG 9. ANALYSIS OF TIME FOR A PRODUCTION ORDER.

or lost time to find the piece sequence time. The whole connection between these quantities is shown diagrammatically by Fig. 9, and as the matter is of considerable importance a summarised explanation of the terms is given below.

TERMS USED IN TIME ANALYSIS

Adjustment time is used for the preparation of work, work-place, machine, tools, materials and work piece, and, if it is necessary, for restoration to the original condition; and in any case for any cleaning up that may have to be done in the course of the process or operation. It is composed of the adjustment basis time and the adjustment lost time.

Piece sequence basis time is the time between the beginning of a process on one piece and the beginning of the same process on the next piece.

Piece sequence time is the above after the addition of an allowance for lost time.

Lost times are times lost or dissipated in activity or delays that have no designed or intended connection with the simple production process. (Example—waiting for heat in a rolling mill.) They need only be taken into account in the determination of working time if they cause decrease of productive effect.

Piece time is the time between the beginning and the end of a process on one and the same piece. In the simple but not rare case when there is no intermediate time between pieces, the piece time becomes the piece sequence basis time.

In some cases it is necessary to divide the basis time into two parts: the *main time* and the *supplementary time*. Main time is that portion of the basis time in which direct progress in the completion of the production order is made. Supplementary time is the part that is regularly necessary, but which only indirectly affects the progress of the work. For example, in the case of the armature shaft for which a working plan is given in Fig. 3 such things as "machine time," "cutting up to stop," "cutting radius," "grinding," etc., make up the main time, and "picking job up," "tightening carrier," "clamping," "unclamping," etc., are supplementary time. This subdivision is only used if the methods of calculation of

main and supplementary time differ, or if it is desired to consider the supplementary work specially for the purpose of reducing it.

The method of using all this information may perhaps be made more clear by taking for an example one of the operations shown in Fig. 3, and supposing that it is desired to find the working time for the production of thirty work pieces. It is assumed that intermediate time is nil (Fig. 8c).

The determination is as follows :—

Adjustment basis time	.	.	= 15 mins.
„ lost „ (12%)	.	.	= 1.8 mins.
<hr/>			
Adjustment time.			= 16.8 mins., say 17 mins.
<hr/>			
Main time	=	8 mins.	
Supplementary time	=	5 „	
<hr/>			
Basis time	=	13 „	
Lost time (12%)	=	1.56 mins.	
<hr/>			
Piece time	=	14.56 mins. say 14.6 mins.	
Then total time	=	17 + 30 × 14.6	= 455 mins.

It should be noted that whilst the same percentage allowance is often made for the adjustment lost time and the basis lost time, this is not always necessarily correct.

In special cases there may be other allowances to be made to the time found in the manner shown; when work is of such a nature as to cause fatigue, rest pauses must be added to permit the worker to recover; if the number of pieces is markedly different in the case under consideration from the number when the measurements were made; if other tools or appliances are used than those originally prepared, or if material of other quality or size is to be worked. In other words, if there is *any* change in the conditions from those that obtained when measurements were made, it must be properly allowed for in using the results, and it may even be necessary to make new measurements under the new conditions.

MAKING WORK AND TIME STUDIES

Notwithstanding the importance and value of the purposes already mentioned that can be served by the carrying out of these studies, it is doubtful if they could be strongly recom-

mended unless something else could be achieved by them, and something else can be and is achieved. One is not content with merely observing, analysing, and measuring work done and time elapsed. The observation and analysis nearly always reveal some possibility of improvement of method and result, and the search for and utilisation of this possibility is really the most important and valuable part of the study.

The *stages* are dealt with below.

(1) **Analysis of Work.**—The operations are examined and analysed as far as is thought desirable. The various times required for the operations or motions are measured, special attention being given to delays and lost time.

(2) **Rationalisation.**—Any improvement in the methods of working suggested by the information thus obtained is carried out. This includes the elimination of delays and lost time, or wasted and unnecessary motions, speeding up of operations, and any alteration of the machine or tools required.

(3) **Time Study.**—Measuring the times necessary for the improved or rationalised process, and recording them in a prepared form.

(4) **Analysis and Criticism of Time Study.**—Further examination of the results of the time study with a view to investigation of the possibility of further improvement. Criticism, and if necessary separation, of unsuitable or doubtful figures. Calculation of piece-work rates, if necessary, or performance standards.

(5) **Further Utilisation of Results.**—Preparing the system of tables for the purposes previously mentioned, and entering in them the relevant figures—process or operation times—from the time-study forms. Testing and proving these figures by further studies.

The extent to which it is worth while to carry any or all of these stages depends both on the nature of the work and its magnitude—that is to say, the number of times the processes and operations are repeated and the possibilities of improvement revealed. Only the man who makes the study can decide this, and he must keep a reasonable proportion between the possibility of achieving results and the amount of study involved in the research.

INSTRUMENTS

The taking of time studies is really very simple, and requires alertness, attentiveness, and powers of observation on the part of the observer, rather than elaborate instruments. If human beings are being observed, a great deal of tact and skill in putting them at ease is also necessary. Where a high degree of accuracy is not required, or where the operations cover relatively long intervals of time, an ordinary watch will serve quite well, and the actual times at the commencement and end of the interval can be recorded, and the subtraction made afterwards. If the operations are not so easy to observe, however, stop watches may be used, and of these there are three kinds.

Stop Watches.—The first is a watch with a single hand and a single button. The first pressure of the button starts the watch, the second stops it and permits the reading of the time taken, and the third returns the hand to zero in readiness for the next operation.

The second is like the first, but has a second button, the pressure of which will bring the hand back to zero without stopping the watch. This permits the time measurement of motions or operations following one another without perceptible pause, and the recording of these measurements.

The third has two hands. The first pressure of the button starts both together; the second pressure stops the secondary hand, whilst the first goes on, and thus permits the reading of the interval without losing the measurement of the next; the third causes the secondary hand to rejoin the first.

Each of these watches has its uses. When the operations are so long and so far apart that the observer has time to read and note between them, the first is quite satisfactory. When shorter periods have to be measured, the second type of watch is considerably better. The time lost in pressing the button and returning the hand to zero is so small that it can be ignored.

When only one watch is used there is always the disadvantage that the observer must withdraw his attention from the work in order to read the watch and write down the time. This takes appreciable time, and consequently leads to errors that may be serious in short operations. If two stop watches are

used, matters can be so arranged as to avoid this. The watches are used alternately—that is, when one fraction of the work is complete the buttons on both watches are pressed so as to stop one and to set the other in motion. The observer can then comfortably read off the exact figure from one watch, and by a second pressure on the button bring the hand back to the original position. This is repeated for every section of the work.

So far we have been discussing the direct measurement of time required for a section of an operation (record unit time). Another method of measuring time is to let the stop watch run continuously from the beginning to the end of the record. The times of the various elements are then read off and entered on the time study sheet. This is known as the continuous method. In order to determine the unit time for each element, it is necessary later to subtract each of the consecutive continuous times from that which follows.

One of the chief advantages of the first method—that of unit times—is that it decreases the work of computation by doing away with the need for subtraction. A further advantage is that the observer can notice when making the record whether the speed of the work varies or not, by comparing succeeding figures for unit times.

The continuous method, when used by a trained observer, has the advantage of being more accurate, particularly when very small periods of time are being recorded. In certain circumstances this advantage may be so important that it compensates for the calculation required later in computing the unit times, and therefore the total time observed is shown directly on the time study sheet, so that it is unnecessary to compare the total time with the sum of the various unit times, which has to be done with the unit method.

For ease of calculation and speed of recording the dials of stop watches used in this work should be divided not into seconds, but into decimals (100ths) of a minute.

Recorders.—In addition to stop watches various kinds of instruments have been designed and can be obtained to facilitate the work of time study. Some of these are automatic and continuous, being actuated by parts of the mechanism that is under observation; others are actuated by the observer.

The latter, most convenient for occasional use, are portable. A precision clockwork causes a band of paper, divided into equal spaces by lines at right angles to its length, to travel at a fixed and pre-determined speed; a number of buttons are available, and the pressing of each of these buttons marks the paper at a certain part of its width.

The distance between two marks made on the paper by pressing the same button twice is thus a measure of the time between the two pressures of the button.

The instrument can thus be used to record a number of different fractions of any cycle, and furnishes a record of the length of time taken by each stage of an operation that it is desired to observe. Some of these instruments are fitted with change speed mechanism, so that the speed of travel of the paper can be varied to suit the lengths of time that are being measured.

The advantage of these instruments is that they allow the observer to give undivided attention to watching work, and recording any occurrence that he desires to remember, whilst operating the buttons with one hand.

Moreover, it enables him to divide the work up in a manner that would not be possible without its use except with the aid of additional observers with their own watches.

The other type of instrument is useful for obtaining, automatically and continuously, records over long periods of the operation of different parts of complicated or extensive machines, and since these are all obtained on one strip of paper and side by side, they present an accurate picture of any sequence.

FORM AND METHOD OF RECORDING RESULTS

It has been mentioned that the observer uses time study sheets on which to record his results. Whilst plain paper or books may be used for this purpose, it is safer and better to plan beforehand not only the information to be collected, but the manner in which it will be recorded, and to provide printed forms, or at any rate previously prepared forms, that have ruled spaces for each item observed, and, if space permits, for the subsequent calculations.

(1) Usually the time for observation and recording is short,

and it will be facilitated by such provision, and will take the attention of the observer from the work as little as possible.

(2) It helps to ensure that all the necessary information is recorded, without any omission that could not afterwards be rectified and that might invalidate the whole study.

(3) It may, of course, be necessary to elaborate these forms somewhat in special cases, but the important point is that they should be planned and prepared beforehand, and not that they should be printed.

They should contain the name, and perhaps a description, and even a sketch of the work piece, the process, the identification both of the worker and of the observer, the total time of the observations, and, when the process is subdivided, columns for times of all subdivisions.

There should be space for the speeds and feeds, material and type of tool, causes of delays, etc.

Although it is convenient, if room can be provided, to give the calculated results on the same sheet, this is not always possible, and special sheets or forms are necessary. There are several different ways of taking averages, and the merits and demerits of these can be, and are, discussed at great length—the normal average method, the central method, the minimum method, the average minimum method, the method of frequency curves, and so on. It is considered, however, that the normal average method is quite accurate enough when one bears in mind that absolute accuracy of result is neither necessary nor obtainable, since there must be errors of observation, and that the most important thing is to obtain *reasonably* accurate results, with a minimum expenditure of time and money.

THE WORKER, THE FOREMAN, AND THE OBSERVER

The normal and natural attitude of a worker towards a time study being made of his work or movements is one of resentment, fear or distrust, or of all three combined, and unless this emotionalism is carefully taken into account it may defeat the purpose of the study, or even prevent it taking place altogether. This makes the personality of the observer very important indeed. Quite apart from the fact that he must know the technique of his job of timing and

recording perfectly, he must also be capable of allaying the ill-feelings of his subject, of winning his confidence, goodwill, and co-operation, and of getting on thoroughly good terms with him. There must be nothing of the "superior person" about him, and he must not be so painfully polite and tactful as to create distrust. He must be able to speak as man to man with his subject, to ask for and receive information about the job, and in this way will often have his attention voluntarily drawn to things that might escape the keenest observer. On the other hand, his own actions must be quite open and plain to see, and he should be perfectly willing to explain what he is doing or going to do, and why, even if the questions be asked merely out of curiosity. Any furtive or secret timing will almost certainly be discovered, and inevitably arouse distrust. Time spent in cultivating goodwill and friendly relations will be richly rewarded. The observer, even if at the outset he knows nothing about the job he is studying, can both give to and receive from his subject real assistance if the correct relations exist between them.

Then the time-study man must also be on terms with the foreman, to whom he must stand in the relation of a friend and colleague, and not in the relation of a competitor or critic. This also is much easier said than done, because he is, in fact, taking up work that the foreman has been assumed to do, largely by instinct; and he is also in fact traversing arrangements and methods for which the foreman has been responsible. His case to the foreman must be that, by virtue of his better appliances, his specialised experience, and the longer time he is able to devote to one small portion of his (the foreman's) job, it stands to reason that he can discover something about it and give help; and that, anyhow, he is not seeking to find fault, but to improve, and to do so with the assistance both of the foreman and the workman.

It should, of course, be known to everybody concerned that the observer has the sanction and full support of the Management, but this should be made to appear rather than be announced, and he should not find it necessary either to invoke or rely upon authority, but should be able to make his own way by his sincerity and soundness of character.

The selection of a type of worker to be studied has been

another rather difficult matter to settle, and there have been several changes and several schools of thought.

Taylor made his observations on the best man he could find, the most skilful, most industrious, and most experienced at the kind of work that he wished to study. His reason for this was that the best man could be more easily picked out than a man defined in any other way, and moreover he believed that the other men would be stimulated to emulate his performance.

Naturally, the times thus observed had to be modified to suit workers of less ability, and, equally naturally, Taylor found it a most difficult task to fix these allowances on an equitable basis, because the difference between workers, and especially between the best of them and the poorest who is still employable, may be so great as to make the whole process seem foolish and futile. Probably arising from this, the thought occurred to study an average worker. An average worker is exceedingly difficult to define, and still more difficult to find or to recognise when found. A definition given in Germany was: "An average worker is one who is thoroughly acquainted with the machines and tools entrusted to him and with the organisation and methods of work in the factory; he should have been employed for a sufficient time on the same or similar work."

One may pause here to remark that this may be a definition of a worker, but there is nothing in it to enlighten us as to his "average" ability; and that the difficulty and the various methods adopted to determine what the term "average" means in this connection lend confirmation to the remarks made earlier as to the use of the word "scientific." The scientific method would have been to study a large number of workers—a number that would vary in magnitude with the variability of their performances—and take the average of the results. This would have been both costly and cumbersome, and the additional accuracy obtained probably not commensurate with the additional cost.

It was evidently more correct to take an average worker, if such could be found, than to take one who might be a very prodigy of skill and to judge others by him. And it was right and natural, having assumed that he had been found and timed, to regard the efficiency of his performance to be 100 per cent.

Obviously this difficulty does not arise in fixing perfect

efficiency of performance for a machine, which can be calculated with exact accuracy. But the difficulty still remained, to determine precisely what is an average performance for a man, and it is a serious difficulty, because the solution of it must necessarily be accepted as fair by the workers, or the whole object of the study—to stimulate effort—is defeated.

A natural guess or estimate might be that the best worker is 25 or 50 per cent. above the average, but actual measurements have shown that one performance may be as much as three times as good as another, and the latter such as would, in rough-and-ready judgment, be regarded as average.

Evidently such variations cannot be ignored, yet, if commensurate corrections have to be used, one may well question the value of any measurement at all.

Many attempts have been made to solve this problem satisfactorily, and it may be well to mention one or two of them. One, taken from an American book, *Time and Motion Studies and Formulas for Wage Incentives*, by Lowry, Maynard and Stegemerton, published in 1927, proposes a system of allowances to be added to or subtracted from a factor by which the observed times given in detail in the book are modified.

It is assumed, and of course it is true, that observed times are influenced by skill, by magnitude of effort, and by the conditions and the consistency of the work; and a table of factors is developed by which the average time observed is multiplied to determine a standard time for the work under consideration.

<i>Skill.</i>			<i>Effort.</i>		
+ 0.15	A1	} Superskill.	+ 0.13	A1	} Killing.
+ 0.13	A2		+ 0.12	A2	
+ 0.11	B1	} Excellent.	+ 0.10	B1	} Excellent.
+ 0.08	B2		+ 0.08	B2	
+ 0.06	C1	} Good.	+ 0.05	C1	} Good.
+ 0.03	C2		+ 0.02	C2	
0.00	D	Average	0.00	D.	Average.
- 0.05	E1	} Fair.	- 0.04	E1	} Fair.
- 0.10	E2		- 0.08	E2	
- 0.16	F1	} Poor.	- 0.12	F1	} Poor.
- 0.22	F2		- 0.17	F2	
<i>Condition.</i>			<i>Consistency.</i>		
+ 0.06	A	Ideal.	+ 0.04	A	Perfect.
+ 0.04	B	Excellent.	+ 0.03	B	Excellent.
+ 0.02	C	Good.	+ 0.01	C	Good.
0.00	D	Average.	0.00	D	Average.
- 0.03	E	Fair.	- 0.02	E	Fair.
- 0.07	F	Poor.	- 0.04	F	Poor.

The factor ultimately determined is called the levelling factor, the average time is the average of times observed, and the standard time is the time to be allowed for the operation when the work is repeated in future.

An example of the use of this table is given in the book. A performance of work is observed and timed, and the observer judges that it is done :—

With poor skill	F1 - 0.16
„ good effort	C1 + 0.05
Under average conditions	D - 0.00
With poor consistency	F - 0.04
<hr/>	
(To be added to unity) Total	- 0.15
Levelling factor	0.85

This means that if the average of the time observations taken is two minutes, the time to be allowed—that is, the standard time for this job—in future is $2 \times 0.85 = 1.7$ minutes.

In another example given in the book the levelling factor is calculated to be 1.14. Thus the observed average time of two minutes becomes a standard time of $2 \times 1.14 = 2.28$ minutes.

In another system it is proposed to analyse the job into motions, and apply such a factor to the time of each motion separately. That is to say, a judgment is to be formed, with regard to each motion, as to the skill used, the effort exerted, the conditions, and the consistency of work.

It may be that these methods were entirely suitable in the cases and for the work for which they were designed and used. It is certain, however, that they cannot be recommended for general use, nor indeed for any use but in a very special case. For general use they are far too complicated and assume too much as to the uniformity of workers and of conditions, and still leave too much to the judgment of the original observer. It would be impossible to make the average worker understand the method, and his acceptance of it would therefore only be given with reservations.

It will be evident from the above that the work of the time-study man not only requires the qualities that have already been mentioned, but also a cool and well-balanced judgment, and since errors are easily possible he must patiently criticise and scrutinise his own work before seeking to impose it upon others, either for payment purposes or as a measure of their efficiency, and if he errs at all, take care that the error is in their favour.

After all, whilst the results of his work must be used for many purposes, the principal and most important purpose is to stimulate the workers always to improve their skill and increase their efforts, and for this meticulous and mathematical accuracy is not only not necessary, but is not even helpful. Above everything there must be generated a spirit of loyalty and co-operation amongst the workers; it is not suggested that any attempt should be made to buy this by excessive leniency in judgment or measurement, but to take care that standards set are *at least* just to all those to whom they are applied.

THE AIMS OF WORK AND TIME STUDIES

It may perhaps be thought, from the length at which we have described the methods adopted in work analysis and time studies, that these are ends in themselves, and are all-important. This is not so; these researches, whilst valuable and important, are only part of a normal management procedure, and in some cases not quite the most important part.

Analysis of work and measurement of time taken in its execution are some of the means taken to the improvement of production, determination of fair wages, and the collection of psychological data and psychological rationalisation, and it may even be truly said that the attainment of the two latter aims is essential to the attainment of the first.

Improvement of Production.—In order that a more balanced understanding may be obtained, it is now necessary to review the subject of work and time studies, and to stress a little more the other parts of the procedure, even if, since we are speaking generally, and not of a specific industry, it is only possible to enumerate some of the things that must be done, and that will be done by any enlightened and efficient management, whether it lays claim to being scientific or not.

We have said that what we have called work and time studies comprise :—

- (a) Analysis of work.
- (b) Rationalisation.
- (c) Taking of time studies.
- (d) Analysis and criticism of time study.
- (e) Utilisation of results.

These processes do not necessarily take place quite in the order named. For example, it may be obvious at the outset, from a careful examination of the work places, the machines, the tools and the people, that some rationalisation is necessary, and if so it will be carried out at once. Again, the analysis of work may point the way to further improvement, and the first time studies may reveal defects and delays that require to be removed before the final time studies for the purpose of measurement are taken and the results collated and made use of.

For the purpose of making preliminary general examinations, nothing much more is required than an inquiring mind and refusal to take things for granted, common sense, experience of human nature and industrial procedure, and a fair spirit.

For example, punctuality in starting and leaving work at the arranged times—proof of this is obtained by the use of clocks operated by individual workpeople which give a record in each case—the number of workpeople in broad relation to the work to be done; their distribution in the plant, and their grading according to trade, age, sex, the wage-scale and system, the relative amounts of day- and piece-work, if both are operative, and in both cases the recording of the times of commencing and finishing individual jobs (time-recording clocks); the provision of sufficient and efficient supervision.

Attention to lighting, heating, ventilation, suppression of noise as far as feasible, and proper provision of safeguards against accidents should be given and repeated. Neglect of or indifference to these things not only reduces production by depressing the spirits and lowering the vitality of the workers, but may lead to absenteeism from sickness, and consequent idle plant, and at times even disorganisation of plans and programmes.

The actual work of a hand worker should be examined as regards the position of the work or material to be operated upon and the disposal of finished work, as well as the position of the tools in use, so that there may not be any unnecessary walking to and fro, causing loss of time and effort. So also, if it is noticed that the worker makes unnecessary movements, he or she should be advised. This kind of advice will make the worker conscious of the possibility of economy of effort and time, and will result in self-improvement.

Then the first studies of any piece of work will inevitably show delays that can be eliminated—waiting for tools or materials, for crane or other service, or for the removal of finished work—places where the rate of production is out of balance with the main stream, or where the distribution of workers is at fault, and where the removal of a superfluous man, or the addition of another to relieve one who is too busy, will result in a quickening of the whole stream. All these things will be attended to before the final time study commences, and it may even be that different arrangements will be experimented with and tested by short time studies.

All this is an extensive field of activity both for the manager and the foreman. It will afford both of them opportunities of studying and becoming known to the individual workers, of attaining skill in judging circumstances and conditions, and will materially reduce the chance of antagonising good workers by lowering times or pay-rates, or of dismissing workers who do not reach standard, when a little patient instruction may enable them to do so.

Moreover, it will do much to reconcile the foreman to necessary changes in methods of management and subdivision of duties, by showing him a job that he has possibly overlooked, or been unable to do properly for lack of time, and in which he can take both interest and pride.

The means of production and all auxiliary equipment, such as machine tools, devices, gauges and means of transport, and all services, will be carefully and repeatedly scrutinised from the point of view of their effectiveness; and the installation of all services, such as water, gas, power, etc., will be examined with a view to prevention of waste, damage, or danger.

Neither will the work itself and the methods by which it is carried out escape attention, for it is here that the work of the designer of product, the designer of method, and the progress planner is decisively tested. For the production of a small quantity, methods may be simplified; for very large quantities they may be improved, even if this involves complications, and a remedy be found for unduly frequent changes of set up of machines or job.

All these things represent what has been called rationalisation, and give almost unlimited scope for ingenuity, planning, and resultant improvement of production.

Determination of Fair Piece-Work Prices.—Since the price to be paid for a particular piece of work is determined by multiplying the time to be allowed by the hourly wage rate, and the latter, or at any rate its minimum value, is usually fixed by agreement between the organisations of employers and employees, the determination of the piece-work rates in a particular case resolves itself into the fixing of a fair time allowance for the job.

It is not the task of the time-study man or the calculator to deal with the question of the hourly rate in any way whatever. His job is to determine fairly and in an unbiassed manner a reasonable time to do the work, and the rest is simply multiplication, as far as he is concerned.

In proceeding now to describe generally the various methods to determine these times, it is necessary to say, and to emphasise, that a time determined by any method or for any purpose is only valid for the purpose and under the precise conditions that ruled when it was arrived at.

Any change whatever in any of the conditions may make it completely inapplicable, and its use without modification cause trouble.

This warning is offered because publications on this subject frequently include examples with considerable detail; so also does the literature issued by makers of machines. The giving of this kind of information is not criticised, and no doubt is thrown upon its accuracy for the circumstances in which it was obtained. But it would be very unwise for anyone to apply these figures in other places and in different circumstances, even if he were going to do the same work on the same kind of machines.

There are so many other circumstances, perhaps apparently trivial, besides the principal ones mentioned, that may affect the result, that it is much better to make new determinations for payment purposes.

If the new results are markedly inferior to those expected, then, of course, an endeavour should be made to find and remove the cause.

The methods used for the determination of time for piece-work prices or rates are :—

- (a) Estimation.
- (b) Calculation.
- (c) Time Studies.
- (d) Comparison.

This division is again used merely to give clearness to the descriptions ; in practice it is not possible to maintain such a separation. The method to be used is always the one best suited to the particular case in question, and often different methods are used for processes or operations closely connected. For instance, it is not unusual to find that for one process the adjustment time is estimated, the main time calculated, and the auxiliary time found by time studies. The time-study man decides, in each case, from his experience, which method he will use. Although the method of time study is very helpful and important, it is not invariably the best method, and consequently is not invariably used.

Estimation is the oldest and simplest method and is, in fact, often used unconsciously by those who, even to-day, deny the importance of the modern determination of working time. Its accuracy depends on the experience of the estimator and the care with which he does his work. Of course it is impossible to fix piece-work rates for jobs that have never been done before without estimating the time in some way, and the nearness with which a careful and experienced estimator will approach the time required is sometimes surprising. In general, however, the use of this method can only be justified in simple cases, or where the article whose time is being estimated differs only slightly, and that difference is readily separable, from some other of which the estimator has had much experience. In more difficult or complicated cases, however great the skill and experience of the estimator, and however careful he is, the possibility of error is so great that it may be unwise to use the result for fixing piece-work rates without confirmation by trial, comparison, or in other ways. Be it remembered that an estimate of time that is too low will penalise the workmen and cause discontent ; an estimate that is too high not only causes the employer to pay too much, but—which is worse—may

demoralise the workers, and defeat the purpose—namely, the stimulation of production.

Not very long ago this method of fixing time allowed by estimation was the only method known and available, and was used by men with experience and intimate knowledge of the work they were dealing with. It usually resulted in bargaining, and the results were not invariably good; and another of the evil results of times, and consequently prices, being too high was the temptation to lower them. All these things tended to bring not only the method but piece-work itself into disrepute.

Calculation.—The second method mentioned is only available when machine work is in question, and then only for fixing the main time.

An example is a machine tool with automatic feed. The dimensions of the piece, number of revolutions, feed per revolution, and so on, furnish the data for calculating the length of actual cutting time in turning a given length of bar. Similar data will serve for planing, drilling, milling, and grinding, but only while the work is automatic—that is, controlled in a positive manner as well as actuated by the motive power. Immediately the work is influenced or controlled by human agency, however, calculation alone is insufficient, and some experimenting is necessary; and there are not many cases where this can be entirely eliminated. There are small variations in the quality of the material, the strength or durability or even the shape of the cutting tools, that influence both the cutting speed and the feed to be used, and so it is not always possible to prescribe beforehand all the conditions of the job, and the skill of the worker has to be relied upon, and results averaged.

In other examples—for instance, a blooming mill, rolling ingots into blooms—the regularity of the supply of properly heated ingots, the skill of the man controlling the manipulators, and other variable conditions affect the time, and preclude the use of calculations based on the fundamental data of the machine as the sole means of determining operation times.

Time Studies.—The third method for the determination of working time has already been dealt with in some detail. Whilst estimation and calculation are based on experience, time studies are principally observations; but this distinction

is not an exclusive one, because both experience and observation are used in practice, the former generally to guide the latter.

The method has been developed and perfected during the last thirty or forty years, the principal improvements having been the analysis of the work, and its separation into useful and non-useful but unavoidable parts, and the recognition of the latter.

To-day a systematic application of the principles stated will result not only in the work being done in the shortest possible time, but a reasonably exact determination of what that time is, so that with this method, fairly and judicially as well as judiciously applied, both fair standards of performance and fair piece-work prices can be fixed.

The determination may be a reasonably short one or a fairly long one, according to the complexity of the job and the number and nature of disturbing influences that cannot be controlled. In other words, a single study of a few hours may suffice; in other cases it may have to be repeated, perhaps several times. In very complex cases, continuous studies for a complete week, even repeated over several weeks, may be necessary. In the former categories will be found, for the most part, studies in textile mills and manufacturing engineering establishments, in the latter will come most steelworks and traffic problems.

Comparison.—This method is carried out by collecting and arranging working times that have been determined by estimation, calculation, or time studies with a view to finding out by interpolation the time required for manufacturing similar articles which differ in size.

It is thus not a fourth method in the strict sense of the word, but only a combination and extension of three other methods, and it is clear that the accuracy of the figures obtained by this means depends first of all on the correctness of the basic figures. A fuller consideration of this method of comparison shows, however, that in many cases its application leads to a check of the accuracy of the original time. A more detailed study of this point would be outside the scope of this book.

Collection of Psychological Data.—If we throw our minds back to what has been said in the first two sections of the last part of this chapter—about improvement of production and determination of fair piece-work prices—we shall realise

that there are many points at which psychological matters have been touched upon, and, in fact, in this section it is only necessary to go back and pick out these points. And since psychological considerations are of paramount importance in management, and have to be allowed for both separately and in connection with other matters, this is a necessary and profitable piece of revision in which we shall discover several methods not yet mentioned that must not be ignored.

The study of psychology, the progress made, and the knowledge gained of human reactions have brought about a great improvement in the application of the methods and principles called by F. W. Taylor "scientific management," and a favourable change in the attitude towards it of those whom it concerns. This change was greatly needed, and without it the work of improving management might have been brought to a standstill.

Consideration of the work to be done must be accompanied all the time by consideration for the human being who is going to do it, and, to be successful as an engineer of production, a man must have this thoroughly engrained in his being.

If, in factories that can be said to be well rationalised on a technical basis, the individual work-places and working methods are examined, and compared with similar work-places and methods, and results of time and production studies are contrasted, considerable differences will be found. These differences are manifested in :—

- (1) Individual differences in the arrangement of the work-place.
- (2) Individual differences in the way of carrying out the work.
- (3) Length of training period.
- (4) Variation of time used per unit of work.
- (5) Fluctuation in level of earnings.
- (6) Volume of rejections.
- (7) Smoothness of work.
- (8) Cleanliness of work, and other features.

A closer examination and inquiry into the causes of these differences in the results of the work show that :—

- (1) In general, the individual features or characteristics of a man's personality are reflected in his work.

(2) With the same human being the fluctuation in the time necessary for the same piece of work increases with its degree of complication—that is, with the degree of intelligence, will-power, and special training required.

(3) The variations of time and quality will be greater the more hand-work replaces or controls machine-work.

If the causes of these variations are established one by one in a workshop, then methods can be evolved to do away with them in so far as they are detrimental, and thus the fundamental object of rationalisation—namely, the improvement and cheapening of production—is fulfilled. At the same time, causes of discord amongst the workers will be eliminated and a healthy spirit of emulation engendered.

In general, it is not easy to say what is the magnitude, or rather the limiting magnitude, of the differences mentioned above. Attempts have been made to obtain evidence, but in most cases statistics are lacking, and even where they exist, they are not detailed enough to be of use, not having been compiled with reference to industrial psychology, but with some other object. It is found, however, that variations in the performances of different human beings are sometimes surprisingly large.

It is not usually possible to apply statistics obtained in workshop investigations as general psychological data, nor is it possible to apply the latter (if resulting from laboratory work) in workshop investigations, because there are considerations peculiar to industrial work not found in laboratory work and other kinds of cases. For instance, it is a fact that if observed times are used for the purpose of fixing piece-work prices, the earnings under those rates tend to assume a level that does not vary, and that level is not usually the maximum that can be earned. It is as though the fact of coupling the performance with remuneration removed or destroyed the worker's ambition to beat his own records as a matter of pride, and as though, at a certain level of pay, his desire for money was satisfied. This steady level of performance will be different in the case of different workers if they are separated or in different rooms, but if they all work in the same place, whether they work as a group or not, there is a tendency for them all to earn about the same amount. One result of this often is that very slow workers

who cannot reach the group standard are either excluded or abandon the work.

It is not possible to give an explanation of these psychological facts, and there is probably no single reason for them.

It is probable, however, that one of the causes of this tendency is the fear that if the earnings regularly exceed a fixed amount, the rates will be reduced. It is lamentably true that this fear is not always groundless, and it is certain that it does operate towards stabilising performance. It is a great obstacle to the success of any attempt to improve production by means of payment incentives, preventing workers both from exerting their powers to the utmost, and also—perhaps more important—preventing them from developing their skill to the utmost. Once piece-work prices are fixed, they should in no circumstances be altered, except with the freely given consent of the workers, in case an error has been made, or when the conditions or practice have been materially changed; no effort that can be made to disarm and remove this kind of suspicion should be spared.

Especially it should be freely recognised that a worker is entitled, by every principle of right and justice, to the product of any added skill that may be acquired as the result of effort or practice.

For a more detailed story of psychological study, research, and progress, the reader is referred to current literature. The effects of the application of practical psychological study, or, as it may be called, psychological rationalisation, are both great and far reaching, and may be summarised as follows :—

(1) The number of workers whose period of training does not enable them to reach the minimum standard of proficiency—that is, the number of “failures”—is reduced.

(2) The time necessary and the cost of training workers to an acceptable standard are reduced.

(3) The amount of material consumed in the process of training is reduced.

(4) The labour turnover—that is, the proportion of workers leaving or displaced—is reduced.

(5) The quality of the work done is improved and the quantity of rejected work is reduced.

(6) The number and severity of accidents are reduced.

(7) The strain on the workers is reduced and their health is thereby maintained and improved.

(8) As far as possible, every condition that is distasteful or tends towards disinclination for work is removed, and in consequence the work is more cheerfully and willingly done.

All these things result directly from psychological rationalisation, and it inevitably follows that with the assistance of work and time studies, the quantity produced in a given time is increased and its cost reduced.

The psychological methods that are applied are vocational tests to guide and assist in the selection of employees and their assignment to particular duties or kinds of work, training, and supplementary and practical instruction.

In a later part of this book will be found examples of work and time studies selected from practice, and a study of these will help to make clear anything that has appeared to be difficult or obscure as the result of the general and abstract way in which the subject has necessarily been treated in this part of the book.

WORK AND TIME STUDIES IN OFFICE WORK

There are certain kinds of office work where work and time studies can be carried out with good effect, as, for instance, in the preparation of letters, circulars, and literature for posting, making up and payment of wages, and work on duplicating machines.

The principles applied are the same as in the works with one or two exceptions.

The work chosen for study in this way must be carefully selected, and the results must be carefully applied. For instance, it is extremely doubtful whether either calculating machine work or typewriting can be regarded as suitable for this treatment, for several reasons. In the first place, they are not purely mechanical work, but require mental effort combined with mechanical work, and any kind of stress or pressure towards faster work is liable to lead to errors. Secondly, in the case of calculating machine-work, the sizes of the figures and nature of calculations will vary, and such variations will affect the speed with which the work can be done. This difficulty can be overcome by setting times for each variation of con-

ditions. In the case of typewriting, either from recorded speech or from shorthand notes, both the matter dictated and the character of dictation vary considerably, and these variations affect enormously the possible rate of typewriting. Then the difference in capacity of typists, as shown by maximum speed attained, is considerable. A very good and fast typist will work at least twice as fast as one that is just good enough to be satisfactory. All these things seem to indicate that these two classes of office work at any rate are quite unsuitable for the fixing of standard performance times, and it is doubtful if even a very large organisation could stand the cost of the investigation work necessary to fix standards that were just and fair; if it could, it is certain that the time and money could be put to better use. It must be remembered that the work of clerks, calculators, and typists is "service" work for someone else's use, and the penalty for failure is paid not merely in a certain amount of clerks' time and stationery, but in a very much more expensive manner. Mistakes in calculation may result in wrong information being given to someone to guide him in making important decisions. Errors in typing may cause irritation and loss of time to people whose time is very valuable. Too rigid a regard for standards, forms, and particular methods may cause the person "served" annoyance and dissatisfaction. And there are many more possibilities of these mistakes occurring in the study of work that is both mental and mechanical than in work that is purely mechanical.

Two guiding principles must always be borne in mind. The only real criterion of the value of a "service" is in the quality of the service and the satisfaction of the person served. The intrinsic cost of the service is usually relatively unimportant.

In order that errors of one kind or another, of omission as well as of commission, shall be reduced to a minimum, the psychological factors require very careful study and treatment.

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CHAPTER IV

SOME IMPORTANT FEATURES OF MODERN PRODUCTION

ONE is rather apt to believe that the methods of work and time studies described in the last chapter are of very recent introduction, and, for that reason alone, are to be viewed with some doubt and suspicion.

But are they so new? Are not the work studies and the rationalisation precisely what every manager and foreman regards as his real daily work, and what he has been trying instinctively, but vaguely and unsatisfactorily, to do? And will any manager or foreman, who sincerely considers the matter and speaks honestly, assert that he has ever been able to satisfy himself in these matters? Is not the entrusting of this work to another who has no other mission in life, and can therefore concentrate on it, a promising attempt to relieve the manager and foremen of the almost intolerable burden of seeing wrong, unsatisfactory, and wasteful methods persist, simply because they are prevented from reforming them by duties not necessarily more important, but more urgent? H. Casson has described a foreman as a man with a bad temper in a hurry, and the same description is not altogether out of place as applied to some managers. The fault generally lies in the failure to realise that the primary duty of a manager is to get things done, and not to do them himself.

Are not work and time studies an adaptation of "training" as is applied to all kinds of sports, but an adaptation that is a good deal less severe and exacting? If "training" is good, indeed essential, for sport, is it not, *prima facie*, likely to be useful in work? Of course it is, and no one who has undertaken it in the right spirit—the spirit of truth-seeking and of trying to find a way out of the haphazard, fumbling, slow, and wasteful methods of unreformed and unrationalised

industry—but is convinced of its value, not only in the workshop, but in every phase of business life.

But the spirit in which the investigation is undertaken must be one of sincere determination to obtain the truth, and the results must be applied in a manner that takes account of, and does justice to every interested party—shareholders, management, and workers.

We now come to some features of modern production, whose present development would be almost unthinkable without the help of work and time studies. The principal features of scientific or modern management may be broadly divided into two groups, the first dealing with ensuring the best performance of equipment, the improvement of old methods, and the invention and introduction of new ones, and the second with manufacturing method in the broad sense, or manufacturing policy. It will be understood that this division is not a real one, and does not operate in practice, but is adopted here for the sake of clearness.

To some extent the first group has already been dealt with—that is, in a general and abstract manner; it depends so much on the type of product of manufacture that it is a matter of technology, and cannot be discussed more specifically here.

In the latter group we have *interchangeability of parts*; *flow of work*; and *standardisation*, and here again there is overlapping and interdependence, but for clear understanding it is better to treat them in turn.

1. INTERCHANGEABILITY OF PARTS

The principle of the division of labour has already been spoken of, and the advantage of employing people in that work which they prefer, or have most aptitude for, has been recognised. It has, however, another great advantage, and that is, the possibility of manufacturing more things of the same type in a given time, from which it follows that production is cheapened. Working always in the same way, the worker becomes progressively more skilled, discovers better ways of doing the job, and, in consequence, the quality of the work is improved, the working time per unit is shortened, and the result is more economical in every way. Therefore, the aim and tendency

in production is always to manufacture more and more similar pieces. This, of course, calls for more and better selling organisation and development, which in turn is assisted by the ability to produce more cheaply, and thus to sell more cheaply. In cases where demand or market does not permit of large quantity production of complete articles all exactly alike, there is often a possibility of quantity production of parts. Three examples of this can be mentioned, one that is well known, another that is rather surprising but which actually happened, and the third yet to be developed. The first is the development of the mass production of motor cars in this country. It is well known that the first steps in this were the specialised production of parts and sub-assemblies in different factories, and their complete assembly by the motor-car builder. The second example was the case of a tailor, who made, in batches, standardised parts of ladies' costumes and other articles of clothing, and assembled them to suit his customers. The third is the case of ships. It is not possible to build ships that are alike, in quantity, because they must differ to suit the trades they engage in and the ports they frequent. It would, however, be possible to standardise a proportion of the plating, both of hulls and decks, parts of bulkheads, deck-houses, etc., and the effect of doing so would be not only to reduce the cost of these parts, but also to shorten the time necessary to assemble and build them into the hull, and thus shorten the time that the building berth is occupied by a ship.

The further evolution goes in this direction, the more important the three above-mentioned features of organisation become. If, however, mass or continuous production of a single standard article is not possible, but only production in series of greater or smaller sizes, the principles are the same and are similarly applied; the economy, however, will not be so great; the methods will not be so refined or so developed; but it is always a matter for consideration how far it is advisable and economic to pursue the principles.

By the interchangeability of parts or groups of parts of a product composed of parts, whether it be a wireless set, a ship, or a child's toy, or even a watch, is meant that these parts can be manufactured in any quantity, and at any place, but so

exactly alike that they can be assembled into the complete product without any further work being done on the individual parts, which can be taken at random from stock.

ADVANTAGES OF INTERCHANGEABILITY

The advantages of such methods of production are apparent and clear. Benefits to the producer are :—

(1) The work of assembly and adjustment is reduced to a minimum. This work is almost purely hand-work, and is nearly always highly skilled work, and is therefore expensive.

(2) The parts can be manufactured in different places and factories, and at different times. They can therefore be made by the manufacturer of the complete article, or purchased from smaller suppliers if this is cheaper or more convenient. The capital required for a single manufacture may therefore be divided over a number of undertakings.

(3) The supply of single parts to customers causes no extra or special work, and the only additional cost is for packing and delivery.

The benefits to the consumer are :—

(1) Replacement for a broken or worn-out part can be readily obtained, with the certainty that it will fit and function properly without alteration.

(2) The cost of these replacement parts and their assembly into the machine or apparatus is lower.

(3) In most cases the replacements can be obtained from stock, at short notice.

Apart from these advantages, which are readily apparent, there are others of greater economic importance, which will be recognised as discussion of the matter proceeds.

ACCURACY AND TOLERANCES

On the other hand, there are difficulties about producing interchangeable parts that have to be surmounted. It appears, at first, that if parts are to be completely interchangeable, they must be perfectly accurate to the dimensions shown on the drawing, and perfect accuracy is technically impossible, and

an approach to it only is possible. The nearer the approach to perfect accuracy, the more difficult, and consequently the more costly, it is. It is obvious, then, that there must be a compromise between the technical requirement of accuracy and the economic factory cost of production, and it may be remarked that the greater the quantity to be manufactured, the greater the possibility of refinement of method and appliances, and the greater the accuracy that can be obtained without increasing the cost of production.

The compromise is to be found by allowing as large a divergence from perfect accuracy as is possible without rendering the part useless or unsuitable for its purpose. This can be made quite clear by an example. Suppose a shaft has to run in a bearing. In order that it may turn freely, the shaft must be slightly smaller than the hole in which it rotates. If it is too small it will be slack, and vibration may result. So the shaft dimension is permitted to vary over a range, and the hole diameter is permitted to vary over another range, so chosen that the largest shaft and the smallest hole in these ranges will fit together, and if the smallest shaft happens to be assembled with the largest hole, the "clearance" will not be too great and the fit too slack. In fixing these ranges, of course, the functions of the shaft and bearing have to be considered, and where a good tight fit is necessary, both ranges will be small, and vice versa. The range, or "tolerance" as it is technically called, is kept as large as the needs of the work permit, so that the cost of production may not be unnecessarily increased.

What do we mean by saying that greater accuracy usually means greater cost? We mean that in any specific process, properly arranged, dimension of product will vary with the condition of the tools that produce it, and whilst deterioration beyond certain limits may bring the process to a standstill it also may be that these limits are too wide to be tolerated, in which case it will be necessary to discard the tools or to recondition them more frequently in order to maintain the required accuracy. This usually does not seriously increase the cost, and it is often doubtful if it is not cheaper to recondition tools more frequently. On the other hand, the accuracy required may be so great or the permissible inaccuracy so small that additional processes have to be used,

and this almost invariably increases cost, sometimes considerably.

The method of ensuring that limits or tolerances are not transgressed is by gauges that have two sizes for one dimension, one of which represents the upper limit, and the other the lower. These are called limit or "go and not go" gauges, and often, when accuracy is very important, the range given by the gauge is slightly smaller than the permitted range, to allow for wear of the gauge and thus ensure that all parts that pass the gauge are acceptable. It will be apparent that the use of limit gauges tends to reduce both the cost of making and the cost of inspecting the parts, as against the use of a single-dimension gauge. In using a single-dimension gauge, the workman strives to make the piece fit the gauge exactly—that is to say, he tries to work with as great accuracy as possible. The newer method of using limit gauges allows as much inaccuracy as possible, but always a fixed amount determined by the requirements of the job.

The introduction of this method of manufacture is not easy; it requires careful preparation, design of parts and fixing of tolerances, design of methods and tools and selection of plant that can be relied upon to give the required accuracy, and not under test conditions only, but in daily service for a reasonable time; design of gauges and inspection system, and lastly—what is occasionally forgotten or neglected—there must be an independent and fairly rigid inspection. The skill that the workers must exercise is also a matter that may cause difficulty, and may even require careful training and practice; sometimes this difficulty can be mitigated by the use of single-purpose or special machines.

In spite of these difficulties, however, this method of working has been well proved to be successful when carried out with due care, and the principal reasons for the success, as already indicated above, are :—

(1) The different parts of an assembly can be manufactured independently of each other, and therefore often in greater quantities.

(2) The adjustment or "fitting" of one part to another in assembling is generally eliminated, but in any case much reduced.

(3) Manufacture with limit gauges is cheaper and more regular and reliable than with gauges showing only one dimension.

(4) The replacement of worn or broken parts is quicker and cheaper.

SELECTIVE ASSEMBLY

Where the accuracy of manufacture is insufficient for the purposes of a job without excessive cost for special processes, there is an expedient available that will give the same result. It consists in gauging and grading into classes, according to important dimensions, the two component parts that have to fit together, and matching the classes according to size. For example, suppose a shaft is required in which it is only possible to allow a total range or tolerance of one-thousandth of an inch in the diameter, when the process it is desired to use will only work to a tolerance of three-thousandths of an inch. Then the product may be graded into three classes, differing by one-thousandth of an inch in nominal dimensions, and these may be matched with holes similarly graded.

An actual example may be quoted. In making umbrella frames, two holes are drilled in the ribs, one near one end; through this latter hole the ribs are pivoted to the ring from which they all radiate, and to the other is attached the strut or stretcher which holds the rib in place when the umbrella is open. These holes can be drilled with all the accuracy necessary as regards position, but the ribs alter in length in the process of hardening and tempering. This variation in length amounts to perhaps three-sixteenths of an inch, and indiscriminate assembly would result in mis-shapen umbrellas. The ribs are therefore gauged for distance between the holes and divided into four classes, then gauged again for overall length, the ribs taken from each of these eight classes being assembled together. Other examples could be given of the use of this method, which is called selective assembly. It is a departure from strict interchangeability, but it permits of exceedingly fine fitting without excessive cost of manufacture.

2. FLOW OF WORK

The maintenance of a uniform and continuous flow of work has become more and more important, and at the same time

more and more difficult to ensure, as the volume of production has increased and as the processes of manufacture have become more numerous, specialised, and complicated.

It is probable that the principle first began to be consciously studied and its importance realised in the automobile works of Henry Ford, where the slogan was said to be "Three feet above the floor and keep it moving."

Why is it so important? The return obtained on capital invested in an undertaking depends not only on the profit as a percentage of the turnover, but also on the relation between the turnover and the capital. One of the secrets of the success of one of the largest distributing organisations in the world is that its policy of buying cheaply and selling cheaply enables it to have a turnover many times its capital, and so a very small profit on each sales item is multiplied many times.

The maintenance of a continuous flow of work affects both the turnover and the capital. By shortening the manufacturing time cycle—that is to say, by reducing the time the article takes to pass through all the stages of manufacture—the output of the factory is increased, just as the steady flow of liquid through a pipe will give more than a discontinuous or choked one. On the other hand, if the work passes continuously, smoothly, and regularly from process to process until completed, the amount of work in progress and material in the factory at any time is very much reduced, and so the capital requirements of the business or undertaking are reduced. Thus a larger turnover is obtained with a smaller capital investment.

A further examination will show that this is not by any means the only benefit obtained by efforts to produce a continuous flow.

STOPPAGE MEANS LOSS

It has been seen that shift time from the point of view of material or work piece is divided into manufacturing time and transport time, or active time and idle time (illustrated graphically in Fig. 10), and whilst it may not be possible to eliminate idle time altogether, it must be remembered that it has to be paid for, just as the idle time of a machine has to be paid for; whilst the material is resting between processes, the

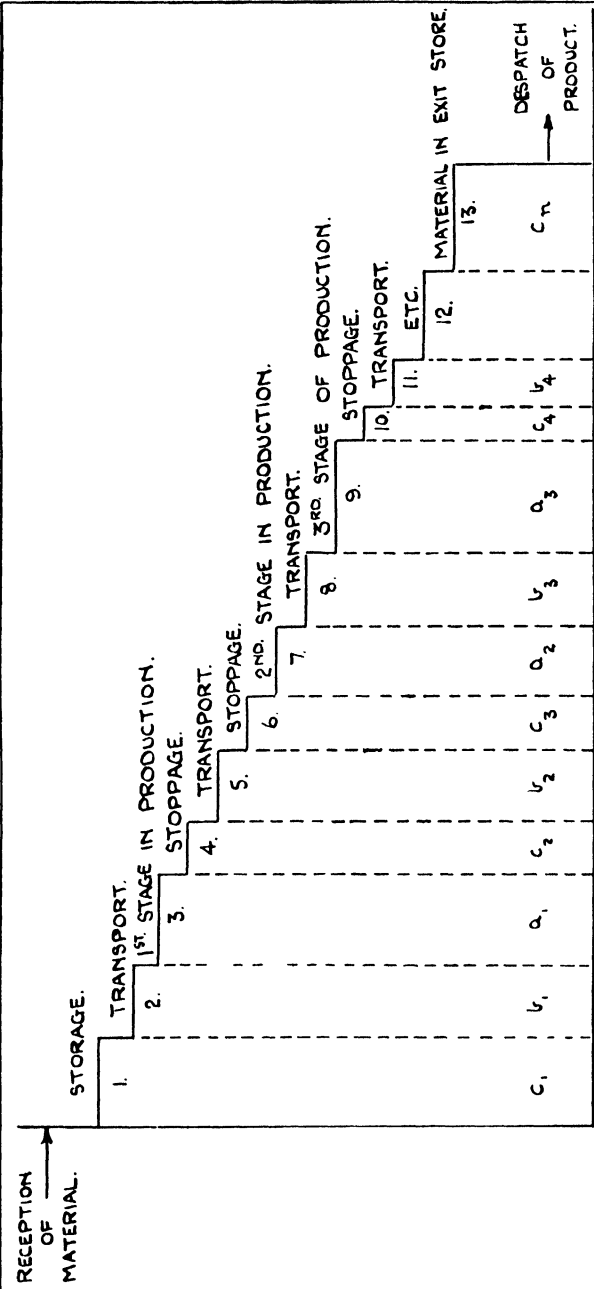


FIG 10. ORDINARY INTERRUPTED FLOW OF WORK.

a_1, a_2, a_3, \dots MANUFACTURE TIME.
 v_1, v_2, v_3, \dots TRANSPORT TIME.
 $c_1, c_2, c_3, \dots, c_n$ STOPPAGE TIME.

capital it represents is idle and giving no return; moreover, rent, rates, heat, light, etc., all have to be paid for the space it occupies; still again, if the material is heavy or bulky the mere putting down and picking up again have to be paid for. All these are very real losses, and furnish a strong incentive to "keep it moving." How can this be done? The first step is to make the stream of production uniform in volume at each process—that is to say, to arrange that the plant is capable of producing at the same rate from beginning to end. Another way of stating this is to say that the production time at each operation must be the same, or perhaps *slightly* shorter at the later processes than at the earlier ones. The information necessary for the achievement of this purpose can be obtained from the work and time studies already described, and when this has been done perfectly, the stoppage times are eliminated and there is no material or work in progress resting (in stock) between processes, or, at any rate, the amount of it is reduced so much as to be easily controllable.

There remains the transport time, and this involves not only the means of transport, but also the disposition of the machines and work places—in other words, the shop lay-out. Both of these must be considered in relation to the circumstances of a specific case; to attempt to give a rule might mislead. For example, it will usually be the better arrangement from a transport point of view to place the machines according to the purpose they serve rather than to the kind of machine. This will give quite a different arrangement from that obtained by putting all the machines of a particular kind together, but in some cases this latter arrangement is essential.

The stoppage time in raw-material stores can to some extent be regulated by adjusting the buying, and so can the stoppage time in the finished-stock warehouse by adjusting the selling, but not quite so easily.

Lastly, the process and operation times will be reduced as much as possible according to the methods generally indicated in the last chapter on work and time studies.

PRACTICAL DIFFICULTIES

The foregoing is principally intended to emphasise the importance of endeavouring to shorten the manufacturing

time cycle as much as possible, and not as a light-hearted description of how to do it. It is realised that it is not an easy process, and it may take a very long time to reach finality, even if, indeed, finality ever can be reached. In some cases the equalising of process times, or balancing the plant, may be relatively simple, and only involve adding a man or two or a machine or two here, or shaving something off there; on the other hand, it may be exceedingly difficult and involve the most intricate and detailed studies of the processes and the machines that carry them out.

An eye must always be kept on the *cost* of this balancing process, and it must never be carried past the point at which it yields a good return. Like so many other things, it is a means to an end and not an end in itself, and a sense of proportion must be exercised; this applies to the selection of the means of transport, as well as to the steps taken to secure balanced production. The most elaborate, effective, or even most efficient means of transport are not always necessary; indeed, there are many occasions when the very simplest passing from hand to hand, or man-handling, are the most economical, simply because they are the best suited and proportioned to the case in point. Elaborate means of transport must be used to capacity to justify the capital invested in them.

The remarks about stoppage time, also, cannot be taken quite literally. In some cases, stores of finished parts are necessary or unavoidable, and care must be taken not to reduce the raw-material stocks to a precarious level. Mathematical formulæ can be evolved for the size of all stocks, and in some cases they may be useful; but in attempting to use them it is necessary to make sure that they fit the particular circumstances. To repeat, the principle is quite clear: it is to shorten the manufacturing cycle by reducing not only the operation and process times, but also the waiting and travelling times between operations and processes, and take advantage of having done this by reducing stocks to a low but safe level, and assist this by buying and selling as closely in accordance with a planned production as possible. It is an important principle, and will repay attention, but the application of it and the method of applying it are a matter of individual selection to suit an individual case.

3. STANDARDISATION

The dictionary meaning of standard that most nearly fits what we have in mind is "that which is established as a rule or model," and of the word standardise, "to make or to keep of uniform size, shape, etc." Perhaps a more general explanation would be: "standardisation is the regularisation or establishment of what is approved as good or valuable, and even shown to be necessary by experience and consideration—weighing the demands of design, production, and economics."

In this place, where we are dealing with features of manufacturing method or policy, and have already discussed interchangeability and flow of work, it is proposed to deal with the narrower aspect of standardisation that relates to size—dimensions—and defer the broader and more general aspects for a later chapter.

It is evident that the advantages of the two features—interchangeability and flow of work—are enhanced if the dimensions of the different parts under consideration are not taken as merely determined by calculation or the experience of the designer, but selected as the best amongst the many possibilities. This will be true even if the standardisation of dimensions is limited to one particular factory, but much more so if a branch or the whole of a particular industry accepts it. The number of standard parts increases, manufacture develops from a single and series production more and more to continuous or mass-production, and all the advantages attributed above are intensified.

The work of designing is reduced; drawings for the part need only be made once, and greater care and thought can be given to methods and accuracy of production without trespassing beyond the limits set by economic considerations; the cost of drawings, tools, fixtures, etc., per unit of production will be reduced, and so will the wage cost of the parts. The standardisation of tolerances in particular is of advantage, inasmuch as it is easier systematically to collect experience in the replacement of worn parts.

Recognition of the importance of these facts has resulted in the formation of standards associations in all industrialised countries. These associations have developed, and are de-

veloping, each for its own country, systems of standards for different industries; they have long been in touch with each other, and have endeavoured to make an international agreement, and it is significant that one of the first subjects treated on these co-operative lines is the subject of tolerances. An international system has been developed that, it is hoped, will ultimately be universally accepted, and so assist the interchange of goods between different countries.

This brief and sketchy description or explanation of technical standardisation can give only a feeble idea of what is really a very broad and all-pervasive and all-important aspect of manufacturing organisation, and although it is intended to deal further with it from another point of view in the next

TABLE 1.
Tool Angles for Various Metals.

Clear- ance Angle, α deg.	Wedge Angle, β deg.	Top Rake Angle, γ deg.	Ap- proach Angle, κ deg.	Lip Angle, ϵ deg.	Class of Material to be Machined.
6	84	0	45	100 to 110	Chilled Iron and very Brittle Brass and Bronze.
8	74	8	45	100 to 110	Steel and Cast Steel of more than 45 tons per sq. inch Tensile Strength. Hard Cast Iron with Brinell Hardness Hn of more than 115 tons per sq. inch. Cast Brass, Bronze and Yellow Brass.
8	68	14	65	90	Steel and Cast Steel of 32 to 45 tons per sq. inch Tensile Strength. Cast Iron of Brinell Hardness Hn of less than 115 tons per sq. inch. Soft Yellow Brass.
8	62	20	65	90	Steel and Cast Steel of 22 to 32 tons per sq. inch Tensile Strength.
8	55	27	85	80	Tough and Soft Bronze. Very Soft Steel.
10	40	40	85	80	All Soft Metals and Pure Alu- minium.

chapter, it is thought wise to amplify what has already been said by an example. The one chosen is the German Standards for Cutting Tools, not only because this shows the essential developments very clearly, but also because English Standards of this kind are not yet published, and consequently foreign ones may be of special interest. The whole work has taken five or six years to prepare, and a considerable volume of detail has been condensed into the fifteen sheets so far published, of which the essence is given in Figs. 11 to 26 and Tables 1 to 3.

TABLE 3.
Sections for Tool Tips.

Sections of Quadrilateral Rolled Bars.					Sections of Triangular Rolled Bars.			
l.	h.				l.	h.	l ₁ .	h ₁ .
	Size A.	Size B.	Size C.	Size D.				
0.236	0.236	0.236	0.394	0.394	0.787	0.413	0.949	0.429
0.315	0.315	0.315	0.472	0.472	0.984	0.504	1.146	0.520
0.394	0.394	0.394	0.630	0.630	1.181	0.595	1.342	0.610
0.472	0.472	0.472	0.787	0.787	1.575	0.681	1.539	0.697
0.630	0.630	0.630	0.984	0.984	1.772	0.772	1.736	0.787
0.787	0.787	0.787	1.181	1.181	1.969	0.823	1.933	0.878
0.984	0.984	0.984	1.575	1.575	2.362	1.039	2.327	1.055

Many meetings of representatives of science and practice, of producers of steel, of tools and machine-tools suppliers and purchasers have been necessary to sift and weigh evidence and opinion and finally to arrive at a unanimous acceptance of the standards proposed; it had been decided that no majority decision could be regarded as sufficient in these matters, because experience had shown that standards are not of practical use unless there is a common conviction that they are, for the time being, the optimum from the technical and economic points of view.

It was first necessary to define the factors involved as simply and as significantly as possible, and to eliminate all possibility

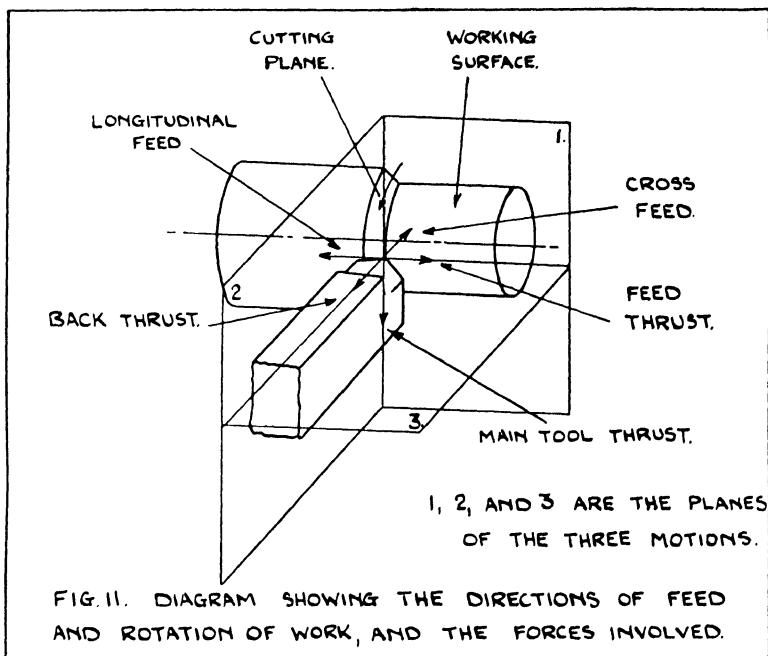


FIG.11. DIAGRAM SHOWING THE DIRECTIONS OF FEED AND ROTATION OF WORK, AND THE FORCES INVOLVED.

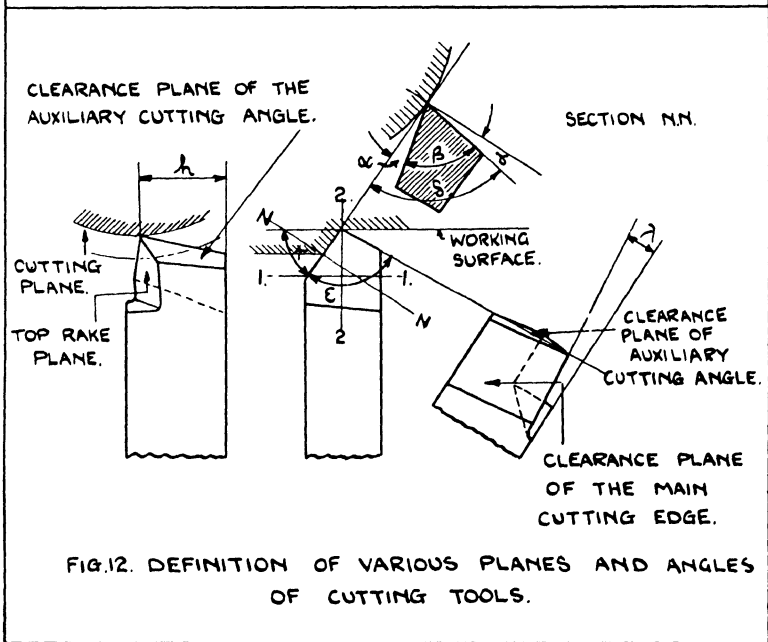


FIG.12. DEFINITION OF VARIOUS PLANES AND ANGLES OF CUTTING TOOLS.

of ambiguity. The terms adopted are shown in Figs. 11 and 12, which give the three directions of motion, the three components of thrust, and the different planes and angles of the cutting tools.

The next step was to standardise the various types of cutting tools, as shown in Figs. 13 to 24. Left-hand tools are the mirror image equivalents of the right-hand tools shown.

The foregoing were necessary preliminaries to the actual standardisation, which involved determining the angles suitable for machining different materials. This was the most difficult part of the work. The results are given in Table 1 and the sectional dimensions and length of the tools are given in Table 2. The angle \angle is not yet standardised, and the figures given for the other angles are only approximate. They may be varied slightly, according to different practical conditions. The top rake angle, for example, can be ground flat or with a radius, and the points of cutting edges may be ground with a radius (say 0.05 of the width of section) for the tools shown in Figs. 13, 14, 15, and 16. The dimensions given in Table 2 are equivalents of the metric sizes given in the original tables.

The sections of material for the tips of tipped tools have been standardised. There are two different types—quadrilateral, as in Fig. 25, and triangular, as in Fig. 26—and the dimensions are given in Table 3.

There is hardly need to point out the advantages of this particular example of standardisation, and the value and convenience of the use of gauges and jigs corresponding to the standardised dimensions in facilitating the provision of the most suitable tool for any given purpose are readily apparent.

This standardisation of cutting tools is an excellent example of the principles it is intended to convey and illustrate, and this alone is sufficient reason for quoting it. When presented to the industry complete and ready for use, it looks very simple, but some attempt has been made in describing it to indicate that the work of preparing it was far from simple or light. If it is remembered, however, that the result of this intensive and concentrated study is a substitute for many individual studies, many times repeated because the results are unrecorded, and usually carried to a much lower degree of perfection, its greater value will be apparent. The "science

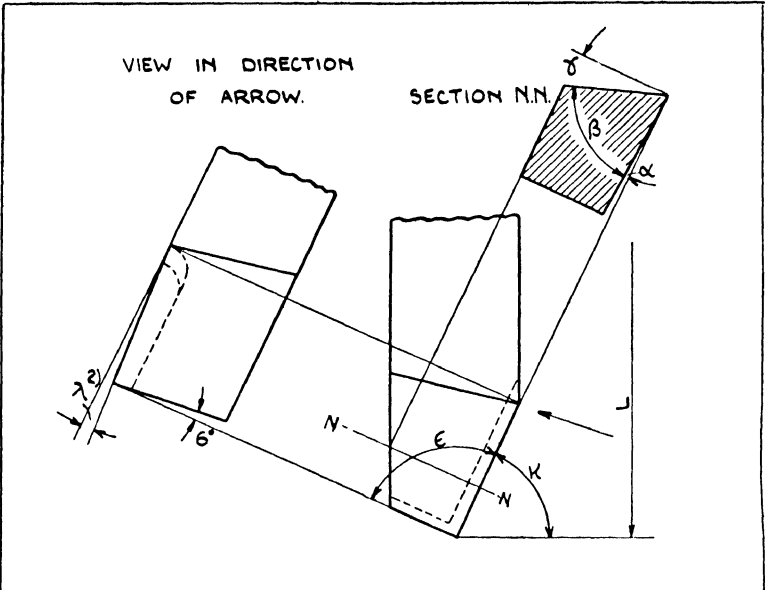


FIG 13. STRAIGHT RIGHT HAND ROUGHING TOOL

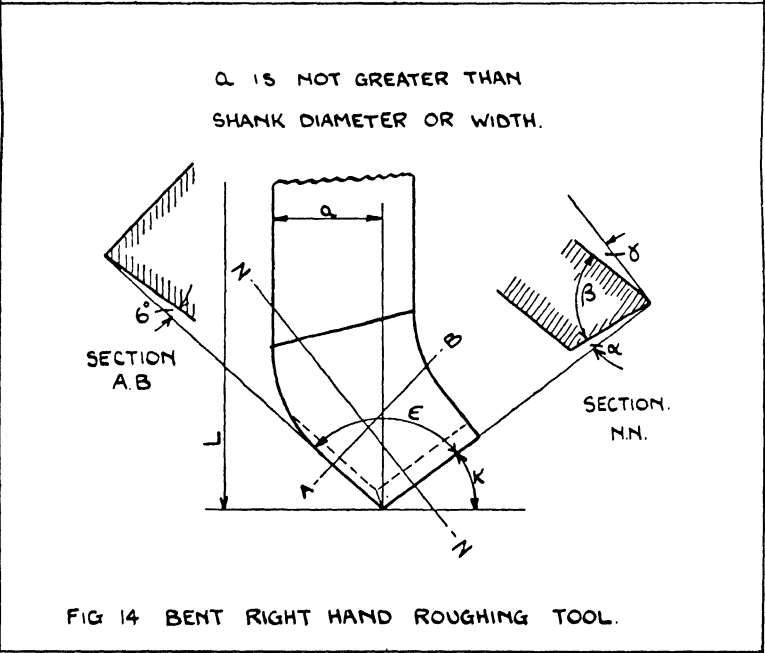


FIG 14 BENT RIGHT HAND ROUGHING TOOL.

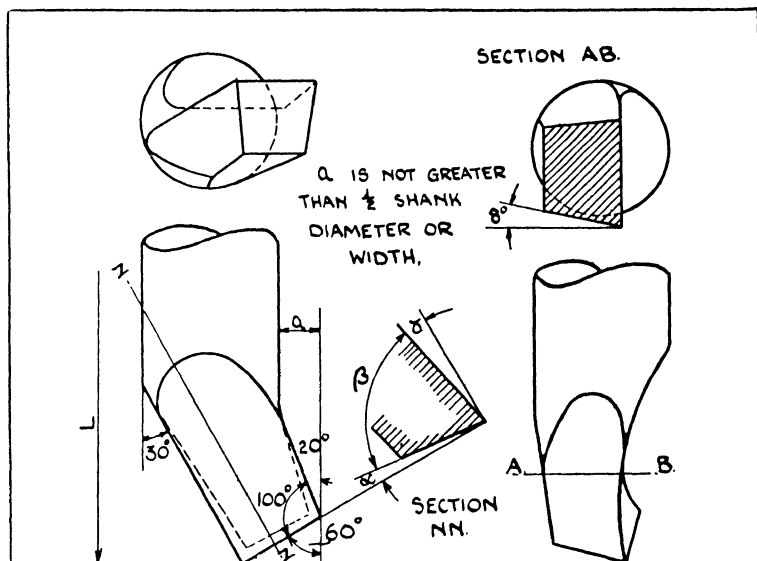


FIG. 15. INTERNAL ROUGHING TOOL FOR BORING STRAIGHT THROUGH HOLES.

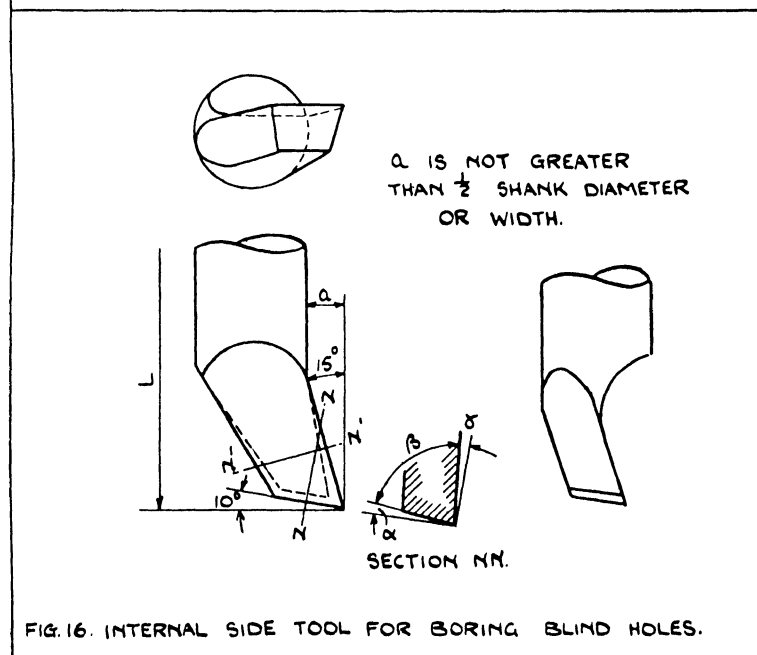


FIG. 16. INTERNAL SIDE TOOL FOR BORING BLIND HOLES.

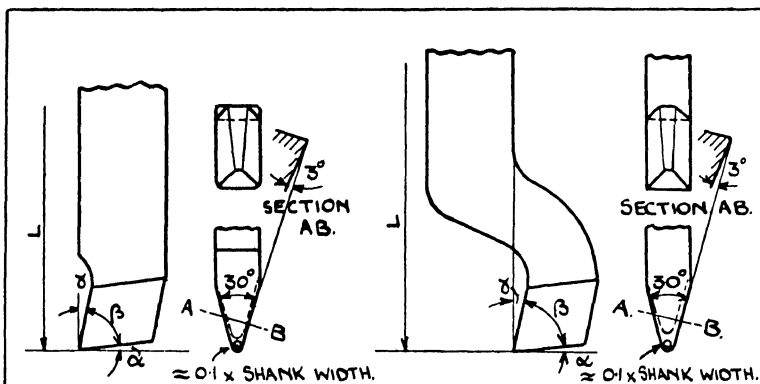


FIG. 17. POINTED SMOOTHING TOOLS, STRAIGHT AND BENT TYPES.

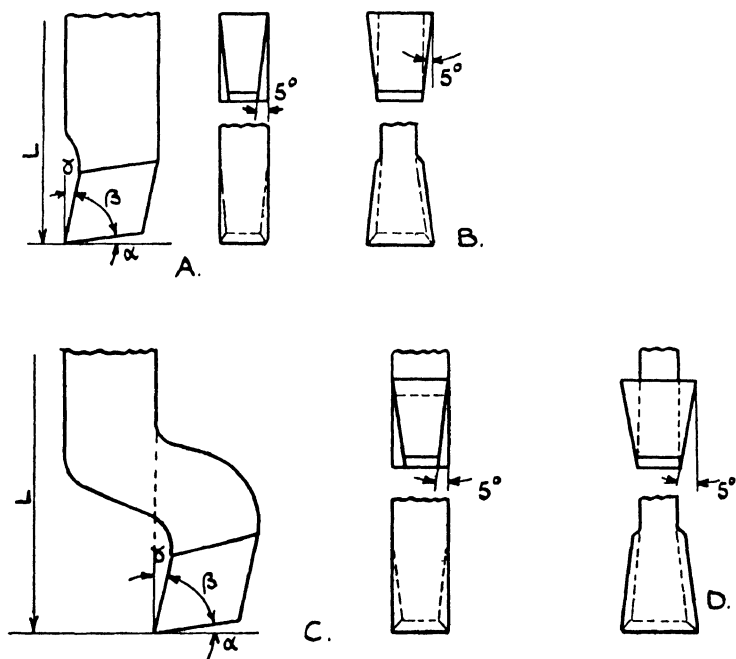


FIG. 18. BROAD SLOTTING TOOLS
 A- STRAIGHT. ; B- STRAIGHT WITH WIDER CUTTING EDGE.
 C- BENT ; D- BENT WITH WIDER CUTTING EDGE.

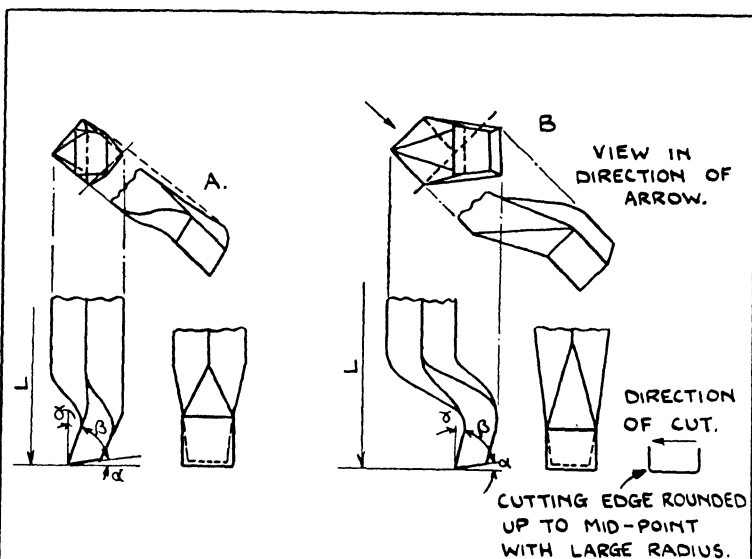


FIG.19. TWISTED SMOOTHING TOOLS - STRAIGHT AND BENT TYPES ARE SHOWN AT 'A' AND 'B' RESPECTIVELY.

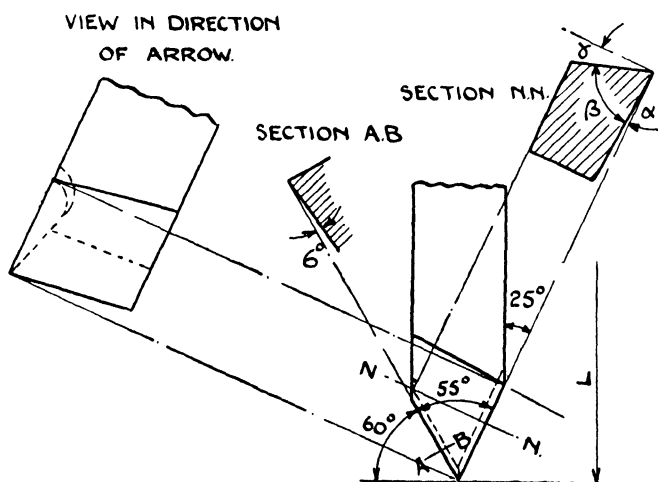


FIG 20. STRAIGHT SIDE TOOL.

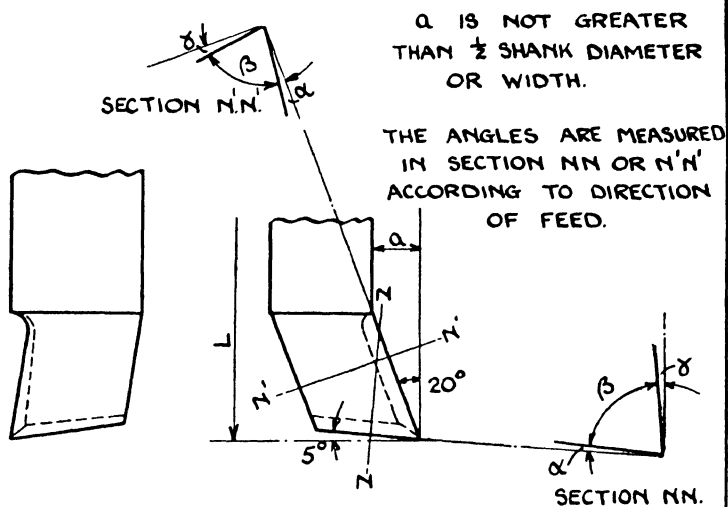


FIG 21. BENT SIDE TOOL

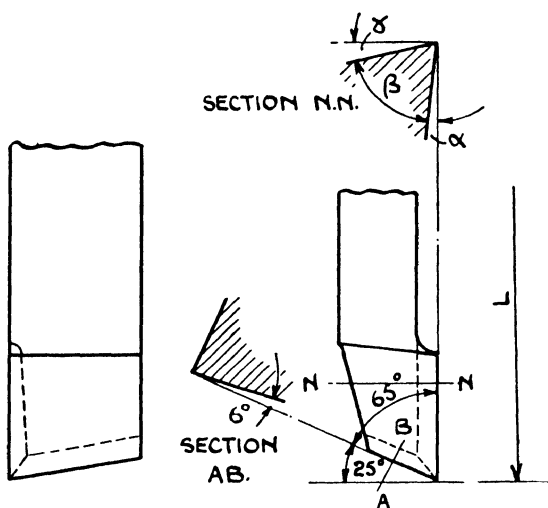


FIG 22. RIGHT HAND KNIFE TOOL.

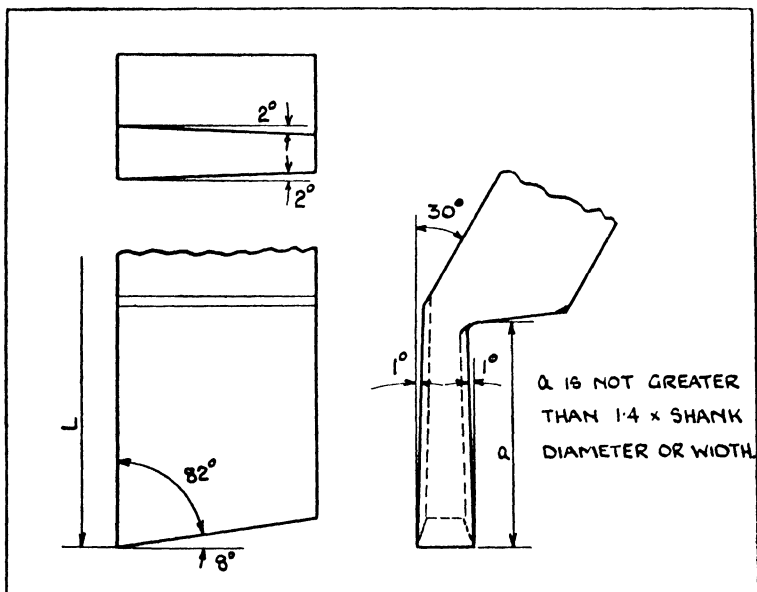


FIG 23. BENT PARTING TOOL LEFT-HAND.

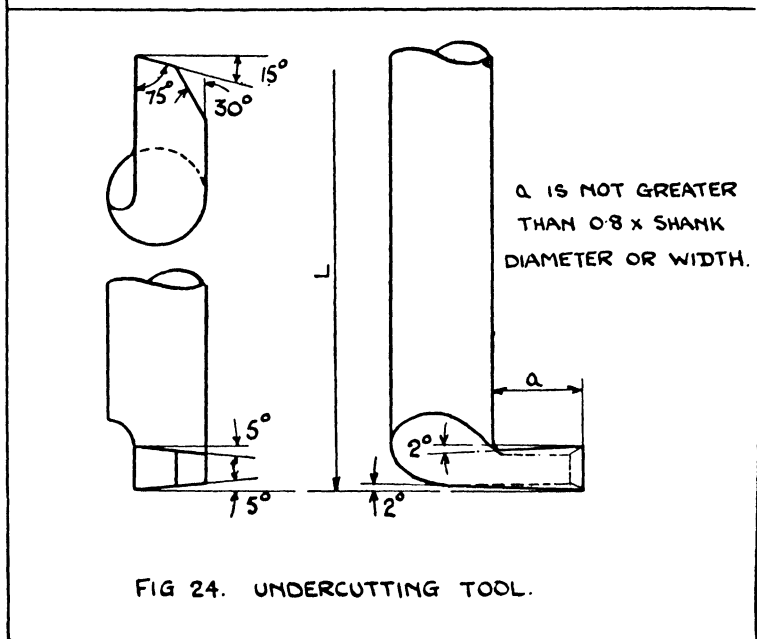


FIG 24. UNDERCUTTING TOOL.

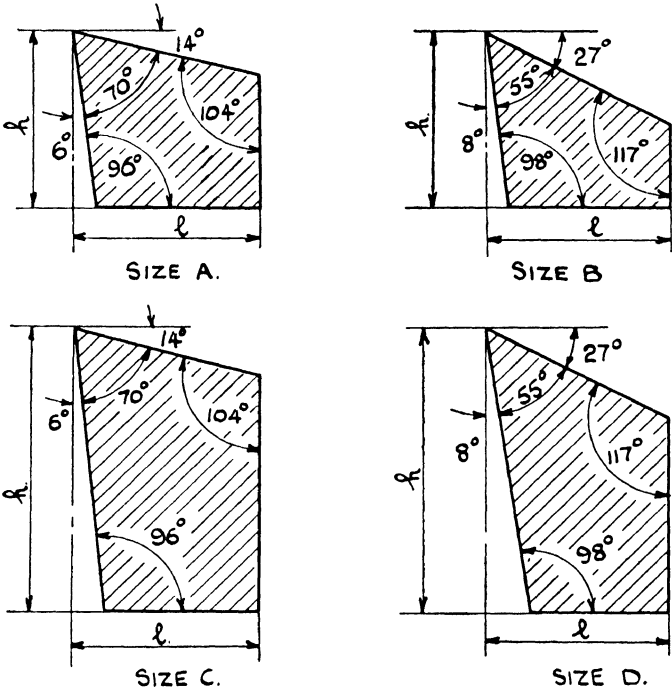


FIG 25. SECTIONS OF ROLLED BAR FOR QUADRILATERAL TOOL TIPS.

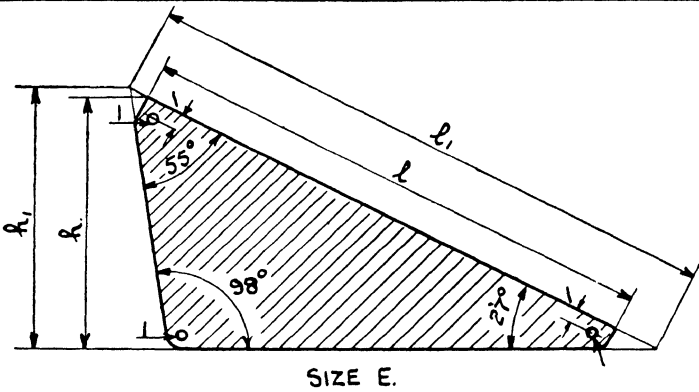


FIG 26. SECTIONS OF ROLLED BAR FOR TRIANGULAR TOOL TIPS.

of standardisation " has not yet been written, and the effect, if it should ever materialise, cannot be forecast.

It will now be apparent, as stated at the beginning of this chapter, that the separation and distinction drawn for clearness between these three features of modern production is an artificial one, and does not appear in this way in practical work. They are complementary to one another and interdependent; interchangeability, for example, requires standardisation as a preliminary, and standardisation presupposes the possibility of interchangeable manufacture; continuity of flow of work results from the combination, but not automatically.

EFFECT OF THESE AND OTHER FEATURES ON THE WORKMAN

It is appropriate, before closing this chapter, to deal with an objection that is often raised to almost any of the principles applied in modern management—mechanisation, subdivision of labour, standardisation, and repetition manufacturing. This objection is that (*a*) it tends to destroy skill and craftsmanship, (*b*) makes the operative a mere automaton, and results in the work being so monotonous as to be, in some cases, injurious to health.

The first part of this can be very shortly answered, and proof of the truth of the answer can be found in the outcry, prevalent at the time of writing, of the shortage of skilled labour, required, be it noted, principally for repetition manufacturing and mass-production industries, and lacking not because it has been "destroyed," but because it has never been trained.

In certain fields of work not less but more skill and craftsmanship is necessary, because a finer and more accurate product is required. In other fields—in the carrying out of operations that have been simplified—workers can and do find opportunities for developing a far higher degree of deftness in specialised work, and this will be recognised and acknowledged by everyone who has had opportunities of seeing it.

The other part of the argument is more serious, if it can be substantiated. But can it? It has been stated many times as something to be feared—certain to occur—but no evidence has ever been produced that it does occur, and repetition of the statement does not make it true. It can be denied

emphatically that monotony hurts *everybody*. Certainly it troubles some, but a good foreman will find these out and give them less monotonous work. Then there are others—and psychologists tend to the opinion that they are the majority—who are unaffected by monotony in the slightest degree.

Generally, it is for medical psychologists to say whether tendency to monotony in work is a danger to health, or whether the human faculties other than those called into play by the work can and will enable the worker to resist it. Moreover, these scientists will be able to prescribe conditions that will be a defence against it, and when they do, industrialists will not be slow to provide them. One has seen and heard of some provisions to relieve monotony; the cigar-makers of Havana have a professional reader to read to the workers; community singing has been developed amongst workers in some cases, and practised with such heartiness as to almost drown the clash of the machinery, and so on.

Monotony *may be* a difficulty to be surmounted, but it can never be a sufficient reason to abandon processes that are so advantageous to everybody concerned with them.

This must not be confused with fatigue that results from a greater degree of, or more sustained, activity. This, as has long been known, does injuriously affect workers. In some cases it results immediately in a falling off in production and in a greater liability to accidents. In some cases it is dealt with by prescribing rest pauses at definite intervals. In others the standard times fixed for the work have incorporated in them allowances for rest that the operatives take to suit their own needs. But fatigue is not a hidden, insidious, or imaginary danger; it is a fact, well known to exist when “driving” or excessive speeding is resorted to, and even an inhuman manager or foreman (not at all often found) is compelled, in his own interests, if indifferent to those of his people, to mend his ways.

CHAPTER V

STANDARDISATION AND INSPECTION

GENERAL APPLICATION OF STANDARDISATION

BOTH the applications of standardisation and the implications of the idea are very much broader than might be supposed from the very narrow sense in which the subject was treated in the last chapter, or even from the sense in which it is usually discussed—that is, with its application to industry in view. And this will be readily recognised if the definitions or explanations that were given are studied carefully and analysed.

If we go back to the origins of standards, we find that standardisation is not a new invention or idea, but perhaps is as old as the human race; men have been standardising, *i.e.* “establishing what is approved as valuable or good,” from the very earliest times, and, in spite of the mistaken belief sometimes entertained, that standardisation tends to retard progress, one does not find much reluctance in the past to abandon obsolete standards and establish new ones. The history and progress of the human race are testimony to the contrary.

The man who first used his foot to measure a piece of land, and to mark a boundary between his own and his neighbour's land, established a standard of length, and one that has given its name to the English standard of length.

By forming stones into axes, and using them for splitting wood, he standardised the splitting of wood and to some extent the tool. Of all the known methods of doing this work, the one that seemed best according to man's experience was selected, and this gave a pattern to all who followed. Thus, those who followed did not have to think all over again about the various possibilities, and the work, once done, was done for ever.

In the same way, other things and other methods were standardised, and thus a group of men living together regularised both their relationship with each other and their

utilisation of material things. A little thought will convince the reader that, considered in this broader sense, there is hardly any field of human activity in which standardisation is not found.

We speak of social standards if they regulate the relations of men to one another, and of material standards if they refer to material things. Both are important in industrial work, although more importance is usually attached industrially to the second group. The first group includes language, calligraphy, systems of notation, laws, regulations for trade and commerce, measures of size, weight, temperature, etc. The second group has already been mentioned, and it is only necessary to say further that the laws of physics and of natural sciences in general cannot be classed as standards, because they are of universal validity, and not dependent on the life and work of mankind.

CHARACTERISTICS OF STANDARDS

Seen from this point of view, we find some characteristics, common to all sorts of standards, which explain their existence and purpose better than any words could do. The first we have already mentioned : standards are closely connected with the evolution of mankind. We may even regard them as a measure of the culture of a nation, since they mark the extent of the general knowledge which has been garnered and classified; the more complete it is, the more power we have at our disposal in pursuing ideals of perfection. Much time and labour which are saved to-day by modern transport appliances such as trains, ships, motor-cars, and aeroplanes, and means of communication such as telegraphs, telephones, etc., can now be used for other purposes.

RELATION OF STANDARDS TO PROGRESS

With standards—as long as they are in force—periods of arrestation occur, but they are not and should not be final stops. Just as the architect provides a landing from place to place when building a high staircase, to enable one to pause to acquire further energy for further climbing, so in the evolution of civilisation pauses are necessary which are to be regarded not

as ends in themselves, but as the beginnings of future developments. Uninterrupted progress—that is to say, continuous change—would use up too much energy, and ultimately lead to exhaustion. It is the function of standards to prevent this. They are the foundations on which we stand, working for progress; but we make this progress only when we are sure that the new ideas and inventions bring a common advantage, never forgetting that “Better is the enemy of good.” Therefore it is clear that standards are not sterile creations, as is sometimes said of them. They pave the way for progress, giving the best that is known at the moment to the whole of mankind without any restraint; preventing continuous change, but at the same time promoting steady evolution.

CO-OPERATION

Another important mark of a standard is that it is not the work of a single person, but the result of enlightened co-operation. A number of people become dissatisfied with the lack of uniformity in some product or process; they wish to avoid uncertainty, and demand a compromise between conflicting interests, and the elimination of struggles which expend energy which could be better employed for other purposes. Therefore standards are an embodiment of the great idea of co-operation which is the foundation of modern society. Without standards our state, our commerce, our traffic would be inconceivable.

Everybody knows that the real bond that unites the nations that comprise the British Empire is a common standard of conduct and a common ideal of life, and that this is assisted by a more or less common language. Similar nations—that is, nations of similar descent, religion, moral ideals—are drawn together, but if they do not speak a common (standard) language, complete understanding and assimilation are not attained.

If they use different standards—for example, of weights and measures—different monetary standards, different railway gauges, the interchange of goods and services between them is more difficult, and thus another promising avenue to unity is blocked or narrowed. Governments are compelled to com-

municate with each other through diplomatic channels, and their respective peoples are left substantially without means of communication.

Thus standards are important not only for an industrial country, but also for its relations with other countries, and anything or anybody that tends to a unification of standards (for instance, the International Standards Association mentioned above) between countries is an active force for better understanding between nations.

EFFECTS OF STANDARDISATION

One of the most important effects of standardisation is the saving of physical and intellectual efforts. A standard is developed by a collection of people who have necessarily greater experience than the single person can possess, and its formulation requires an amount of labour which is only justified economically by the repeated and general use subsequently made of it. This affords the best-known solution available for common use, thus avoiding loss and saving time which, as has been said above, may then be used for other purposes.

All these characteristics of standards in general are to be found in the different standards used in industrial undertakings, where perhaps not one of the different functions, offices, and workshops is out of touch with the idea of standardisation, especially if not only mechanical but also social standards are included. Conventional methods for use in constructional drawings, also printed forms for orders, stores requisitions, wage tickets, invoices, cost accounting books, statistics, etc., regulations for workmen and employees regarding their conduct in the factory or office—all these things are standards in the sense explained. The work of production, inspection, selling, and buying is influenced by the idea of standardisation. Taking all this into consideration, together with special technical standards of a particular factory and the common standards of a Standards Association, as far as they may be of value for the factory, there is a great number of standards, which should be collected in a "Book of Standards" for the undertaking, and which gives guidance in all important internal questions in the works.

By studying this "Book of Standards," the newcomer will become accustomed to the circumstances surrounding him at the very beginning of his work, and the employee already working in the concern will find instruction, in many cases, as to how to develop his work according to the methods in use, and yet without doing anything contrary to established practice.

A "BOOK OF STANDARDS" AS A "GUARDIAN OF TRADITION"

The standards so collected have yet another very important function, especially in times which are characterised by the necessity for quick changes in methods or customs according to market fluctuations. If all alterations of standards are recorded in the "Book of Standards" of the undertaking, it gives a true picture of the stages of the development by which the existing modes of working have been reached. It is clear that it is also possible to show whether a false step has been taken at any time or whether mistakes have been made necessitating subsequent rectification. By studying these records, everyone learns to avoid such faults and to recognise the reasons why any particular method is used, any special construction chosen, or why instructions are given in just the way in which they are given. The whole "history" of the undertaking is to be seen from the "Book of Standards" and the often-regretted "lack or loss of tradition" may thus be avoided.

This lack of tradition may cause great harm in many cases where a new man has to replace a veteran, whose services have been lost by death, by retirement, or by his accepting a position in some other undertaking. This is more important the higher the position the man has occupied. It is very seldom found that all that the former holder of a position has done is wrong. Changes should not be made without a full knowledge of the reasons of the earlier methods, and a complete change of practice merely for the sake of change, which is effected only too often, has frequently entailed great losses. It should never be forgotten that an industrial undertaking is a living organism, and that a very careful hand is needed to guide it from one state to another, even if the former has been found to be bad and the new one will apparently be a very much better one. When changes are contemplated, a "Book of Standards" care-

fully kept as shown above may be a very great help to a new manager.

INSPECTION

Considering all these ideas on standardisation in the broadest sense of the term, we recognise the strong connection that process has with another which is of more importance in modern industry than in former times. This is the idea conveyed by the term inspection. Before we explain this connection, we should at first consider what "inspection" strictly means. As long as we have to work with human beings, with all their imperfections, faults of various kinds cannot be avoided. The function of inspection is to diminish as far as possible the losses caused by these faults, by discovering and rectifying them at the earliest possible moment, without, however, establishing an organisation too costly in relation to the savings effected.

DEFINITION OF INSPECTION

Inspection is the comparison of a condition, a quantity, a dimension, or an effect, etc., as it actually is with a condition, quantity, dimension, or effect, etc., as it ought to be. It consists, in short, in comparing the actual with the ideal.

It will, however, be remembered that the ideal is frequently unattainable. This has been seen already in considering the interchangeability of parts; the dimensions given in the construction drawings cannot always be adhered to with absolute accuracy in practice, for technical and economic reasons. Thus in inspection, the theoretical ideal must be replaced by a practical approximation to it, the closeness of this approximation being fixed partly by economic considerations, but to an even greater extent by the purpose for which the article is intended.

In every industrial undertaking there are four essential factors for production :

- (1) The human complement.
- (2) The plant and equipment.
- (3) The material, semi-finished material, finished products and goods.
- (4) Money and capital.

Each of these factors has to be inspected or tested in three directions—namely, according to whether :

(1) The requisite quality is attained—that is to say, the question “ How ? ” has to be answered.

(2) The desired quantity is manufactured—that is to say, the question “ How much ? ” has to be answered.

(3) The products are manufactured within the scheduled time and are ready by the date promised—that is to say, the question “ When ? ” has to be answered.

In accordance with these considerations the following scheme may be used :

Group.	Quality.	Question.
Human Be- ing.	Health, protection from accident	How ?
	Ability and Efficiency, presence	How much ?
	Degree of Activity (time)	When ?
Plant and Equipment.	Conditions, Accuracy	How ?
	Workshop Space, Efficiency	How much ?
	Degree of Activity (time)	When ?
Material Pro- duct Goods.	Quality, Measure, Weight	How ?
	Quantity, Number of Pieces	How much ?
	Date of Delivery	When ?
Money and Capital.	Validity of Accounts Receivable; Possi- bility of Realisation or Sale of Goods,	
	Material and Equipment	How ?
	Value	How much ?
	Terms of Payment	When ?

The inspection and testing purposes of factors in the first, second, and third groups have already been dealt with, and the underlying principles may be easily recognised in the chapters on Organisation and on Work and Time Studies.

The fourth group will be dealt with more fully in the sixth chapter.

Although it is not intended to give details at this stage, it is advisable to enlarge on the first group as given below.

As already stated, the theoretical ideal is not attainable, and moreover, even the practical approximation to it cannot be achieved without some trouble. It is the purpose of inspection to obviate this trouble as far as possible.

SOURCES OF ERROR

In human beings the sources of error are physical, mental, and moral imperfections. In the plant imperfections are

caused by wear and tear, climatic influences, incorrect use, inadequacy, and obsolescence. Imperfections in the material are caused by products and goods varying in quality, inaccurate dimensions, faulty checking and weighing, pilfering, breakages, shrinkage, leakage, etc. Money and capital are threatened by the possible insolvency of the customer, by factory fires, strikes, and in particular by market fluctuations—whether seasonal or due to fashion—competitive new inventions, or decreased purchasing power of the consumer.

Methods of inspection or testing naturally vary widely according to the object in view in each case. In most cases they may be developed in the following stages :—

- (1) Determining the actual nature and properties.
- (2) Comparing the actual with the ideal.
- (3) Establishing the result.
- (4) Diminishing future loss in the light of the established facts.

The most accurate testing is possible only if accurate methods of measuring are available. Its principles have already been explained. Attempts are made not only to measure things like size, volume, weight, temperature, time, etc., but also the physical and mental qualities of human beings. It has already been mentioned that a new science called “industrial” psychology” has been developed and that valuable results have been obtained; but the limit of the usefulness of these investigations has also been pointed out and warning against exaggerated use of and reliance on the results has been given.

In view of the great importance of this matter, it may be better to repeat and summarise our opinion about it.

Sufficient progress has not been made to enable the laws governing so complicated an organism as a human being to be recognised in detail, and a little knowledge is often a dangerous thing. In testing one quality, it is difficult, if not impossible, to avoid the influence of other qualities on the result, and thus to give the perfectly true impression of the individual under test. If it were really possible in a particular instance as in a laboratory to separate the quality sought from all others during an experiment, there would not be much gained in

practice, where such a separation is impossible and the various influences of the surroundings could not be eliminated. We do not wish to be misunderstood; these researches have admittedly afforded valuable assistance in many cases—for instance, in the selection of those best fitted for industrial apprenticeship or training. Indeed, it may be claimed that every man who aspires to a leading position, and especially every production engineer, should know of and employ the laws of industrial psychology; and readers will find in this book repeated reference to the necessity of psychological understanding. But exaggerated claims have been made, in some cases, by certain exponents of this science, and in any case some doubt about using new and apparently irrelevant (certainly relatively unproven) methods, in a problem of admitted difficulty and delicacy is both natural and justifiable. Most of the leading industrial psychologists acknowledge the limit of their science and give warnings against the results of laboratory experiments being translated too easily into practice, and we wish to repeat and emphasise the warnings.

ORGANISATION OF INSPECTION

Methods of accounting will be referred to later. The organisation of inspection of the other three groups need only be referred to briefly here. Plans must be developed as to where and to what extent inspection should take place; instructions should be given as to how it shall be effected; co-operation between inspection and production must be secured. Although they should be independent of each other, that does not mean that one is superior to the other, and still less that they are opposed. The results should be collected and recorded for future use. All this must be done with the cost in mind, and the testing apparatus must be such that its cost does not exceed the value of its indications. It is impossible to give figures universally valid, or indeed anything but a very rough guide; but experience has shown, for instance, that in normal manufacturing undertakings the wages for the inspection of material in all conditions, raw, semi-finished parts, and finished products, should not exceed 2 to 3 per cent. of those paid for production itself.

STANDARDISATION AND INSPECTION

If standardisation is done in the way described above, it is an organising and testing activity influencing perhaps all departments, offices and workshops of the undertaking, and dealing directly with all but one of the four groups—namely, material, technical apparatus, and personnel—but with the fourth, money and capital, only indirectly. The industrial undertaking is often compared with a human being, whose head or brain is represented by the offices, and the limbs and body by the factory, the workshops, and the technical equipment. If this analogy be extended a little, that portion of the organisation that carries out inspection may be regarded as the conscience, that “still small voice,” which seeks to keep the undertaking in right paths.

To make standardisation effective, a high degree of efficiency of inspection is required, especially in regard to material in all forms and conditions, and all parts of the technical equipment; and in order that the inspection may be efficient, both the methods and equipment used for inspection must be standardised. There is thus a very close affinity and interdependence of these two features or functions, one conditioning the other, and only by a high degree of development of both of them can the best results be obtained. For this reason it would, in many concerns, be reasonable to combine the exercise of these two functions under one member of the organisation, and that member an important and highly placed one.

This is not the view generally taken, and often standardisation is regarded more or less as a side line for the drawing office, while inspection, instead of being an ever-active and valuable aid to production, is regarded as a rather disagreeable necessity and is no better done than it need be.

This is unfortunate, and the consequence of it is that the quality of the product suffers, and is not as good as it ought to be; and not only this, but the production also suffers both in quantity and cost to an extent that is not generally realised.

In any case, however the functions of design, standardisation and inspection may be allotted or combined, it is highly desirable that the inspection function be exercised by a highly placed and independent officer, so that the voice of conscience may be heard by everybody.

CHAPTER VI

THE ELEMENTS OF ACCOUNTANCY

GENERAL SURVEY

FINANCIAL control, or ensuring the economic use of money as capital and in current expenditure, brings us into the important field of cost and works accountancy, and the statistical work on which it is founded. It is proposed only to examine this field in so far as it directly concerns management, and to treat of those principles which ought to be made clear to everyone engaged in industrial work, leaving details to specialised publications.

Guided by correct principles, one may not only check and correct one's intuitions as to the economic use of manufacturing resources, but, what is perhaps even more important, learn to think from the economic standpoint.

The acceptance of money as a measure of the economic use made of manufacturing facilities and services has already been mentioned, and the function of cost and works accountancy is to reflect this use in as true and accurate a manner as is practicable and advisable.

Such accountancy may be likened to a mirror reflecting the economic result of every occurrence in the works, and it is the duty of all those responsible so to grind or polish the mirror as to ensure a clear and undistorted picture of what has happened, and from this to draw conclusions as to what is likely to happen in the future.

The picture shown us in our mirror is one of a continuous flow of material and labour, reflected as a corresponding flow, in the opposite direction, of the money value expended in its provision. That is, material and services are received into the works at the one end against payment out of the works of money, and at the other end money is received inwards against the delivery outwards of the finished product.

Economic use of these manufacturing facilities should result in a profit, and, consequently, the money received for products sent out of the works must exceed that paid out for goods and services. In the event of this not being so, *i.e.*, where a loss is made, the continuous cycle of internal flow must be maintained by the introduction of fresh capital. A diagrammatic representation of these relations is given in Fig. 27, which, taken in conjunction with Fig. 1, should assist in making this point clear.

A closer analysis of this economic use of monetary resources can be made, either generally by examining the matter over a definite period of time, or in detail by concentrating attention on a definite unit of production and considering the time taken for that production. Since in both cases we can think of the past and the future, we can approach the subject from four different angles.

In the examination we shall also need to have regard not only to pure cost accounting functions, but also to the attendant and correlated work of pure accountancy as dealt with in book-keeping, and financial statements. To separate these functions, as is often done, is a mistake, and leads not only to overlapping of work, but to relative inaccuracies. Cost statements should be accurate, and therefore capable of transference to the financial books of the company, if they are to inspire confidence. To make the best use of both of these branches of accountancy practice, it is essential that close co-operation should exist between them, to ensure that each item is determined only once, and by that section best qualified to do so.

For the present purpose, and without going into the subject in too much detail, it will be convenient to treat the matter in the four main divisions necessary for financial control—namely, book-keeping, collection and distribution of costs, job costs and budgeting.

(1) **Book-keeping** deals with the record of past occurrences during a definite period—year, month, week, etc.—and supplies the information necessary for the compilation of the Manufacturing and Trading Account, the Profit and Loss Account, and the Balance Sheet.

(2) **Collection and Distribution of Costs** deal with the relation of the book-keeping figures for offices, workshops, services, etc.,

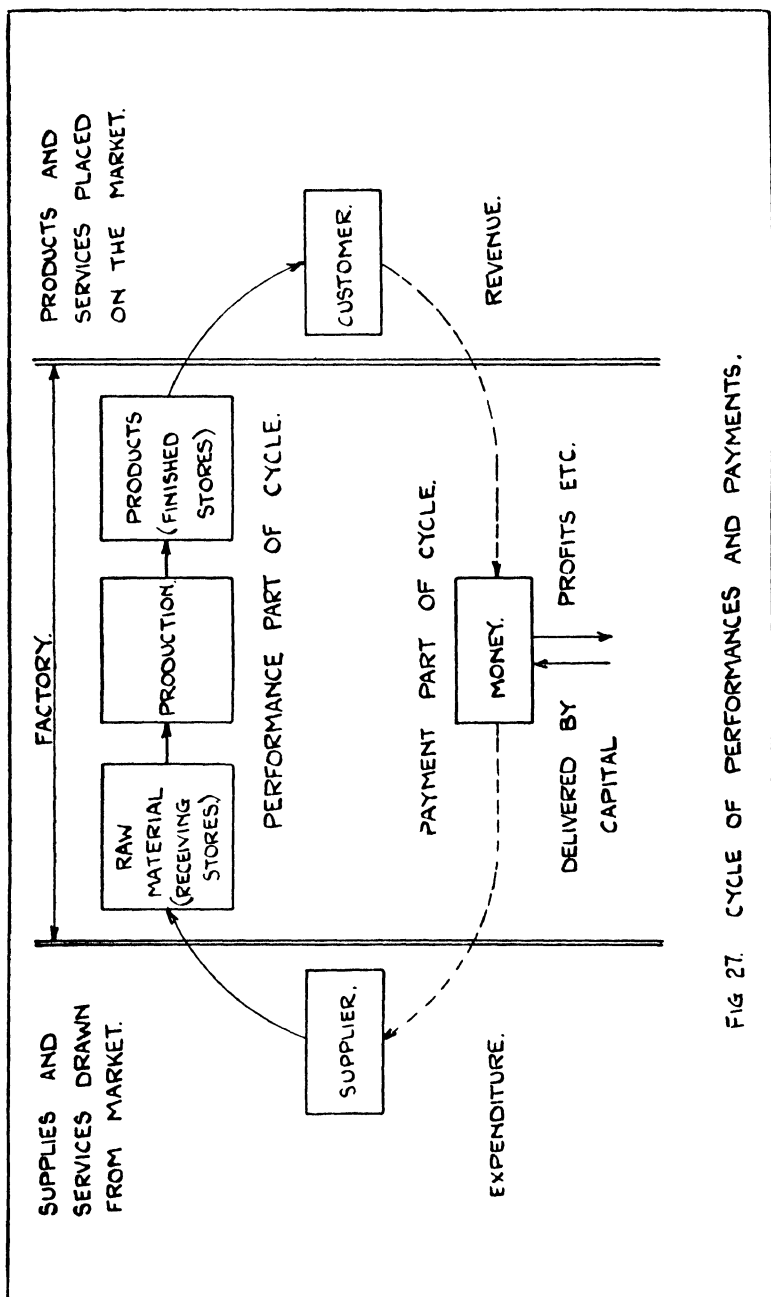


FIG 27. CYCLE OF PERFORMANCES AND PAYMENTS.

in which, and for which, these costs have been incurred. This provides, on the one hand, a basis for investigation and comparison between the cost positions of the different sections of the undertaking, and, on the other hand, for the calculation of the costs of individual job orders.

(3) **Job or Order Accounts.**—These are the total manufacturing costs of individual orders. Where they are a record of past performance, they show where a profit or loss has been made; where they are an estimate of future performance, they provide a guide for the suitable selling prices, and if the selling price is fixed and known, as to the desirability of the business.

(4) **Budgeting** is the last division, in which the information comprised in book-keeping and collection and distribution of costs is directed to the future, and not to the past.

There are, of course, other aspects of this important matter of cost control, arising out of the close connection of the four main divisions just enumerated, but to deal with these fully is beyond the scope of this book. The matter may, however, be more clearly brought out by further classification of costs as to :—

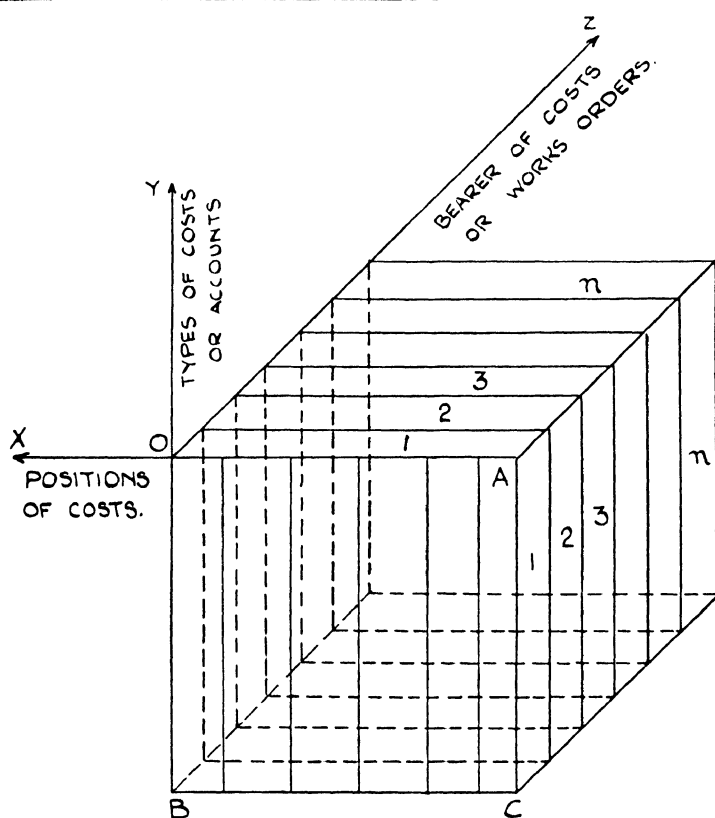
(1) The nature or type of costs.

(2) The position of costs, by which is to be understood the location or function in which or for which the costs arise.

(3) The bearer of costs, by which is to be understood the different jobs to which the costs are to be distributed in such a manner that the total expenditure is completely recovered, and each job bears its proper and just proportion of expense.

Of these three categories, (1) generally called Accounts, is used in book-keeping under the double-entry system, (1) and (2) in the collection and distribution of costs, and (1), (2), and (3) in the calculation of job accounts. A diagrammatic representation of this threefold relationship is given in Fig. 28.

It should be emphasised that the same numerical quantities—that is, covering figures and amounts—are used as a basis in the four main divisions necessary for financial control. The groups are distinguished from one another only by the use made of them according to the different points of view, and partly, as will be seen later, according to the different principles of collection and methods of calculation.



1. AXIS Y. THE LIST OF TYPES OF COSTS, THE LIST OF ACCOUNTS, IS USED IN BOOK-KEEPING.
2. AXES X-Y. THE PLANE OACB REPRESENTS ON ONE AXIS THE TYPES OF COSTS AND ON THE OTHER POSITIONS OF COSTS AND IS USED FOR THE COLLECTION AND DISTRIBUTION OF COSTS.
3. AXES X-Y-Z. THE LAMINAE 1, 2, 3, n REPRESENT THE DIFFERENT BEARERS OF COSTS OR ORDERS TO THE WORKSHOPS, THEY ARE THE SUBJECT OF THE JOB ACCOUNT.

FIG. 28. THE THREE-FOLD RELATIONSHIP OF COSTS.

Often, in spite of the common basis, results apparently inconsistent with one another arise, which in reality are quite in order if the different purposes which they fulfil are taken into consideration. For instance, the actual cost price of a particular material will be used for book-keeping, and the anticipated cost price for estimates for future work. Wherever it is not quite clear, from the nature of these differences, whether they are justified or not, a check must be instituted to find out if a mistake has been made. The points arising out of such further investigations will not be dealt with here in detail.

All figures used in cost control are taken from supporting statements; book-keeping in the administration of stores and stocks and the wages book-keeping which originate inside the undertaking; and invoices from the suppliers and to the customers which are connected with the outside. No material, in whatever condition, should be issued from stores and stocks without a written order, generally in the form of a requisition, addressed by the Works-Order-Office to the storekeeper. No work should be done, or wage expenditure incurred, unless a voucher or authority in the form of a Time Sheet for a day worker, or Wage Ticket for a piece-worker is made out, or a certificate is given that the work has been done and the expense incurred. The compliance with such regulations as these must be absolutely rigid and complete, because the figures provided by these requisitions or vouchers form the basis for the whole system of financial control, and unless they are punctiliously carried out the whole of the accounts will be inaccurate and useless.

In this connection it should be pointed out that the average technical employee in the shop has, in the authors' experience, little or no regard for the importance of filling up forms in a correct and accurate manner, so that vigilance in this matter is very necessary.

On the stores requisition the quantities to be issued are first entered, and later extended against the price per unit to obtain the amount of value, but the prices per unit selected in practice will vary with shop conditions. Here we will only consider the invoice price for this purpose, pointing out, however, that in many instances this is increased by the cost for packing, freight, customs, etc., which are paid before material is received

into the factory. On the time sheets, to obtain the total value, the time entered must be multiplied by the workers' hourly rate.

OVERHEAD COSTS

Now comes a very important and entirely different aspect of the cost question—that of Direct or Individual Costs and Indirect or General Costs. Direct Costs are all those costs which can be allocated without difficulty and trouble to an individual manufacturing order; for example, labour and material known to have been specially used for the job to which they are charged. Costs that cannot be thus allocated—as, for instance, power, light, heat, etc.—are classified as Indirect. Accordingly, both material and wages are divided as to Direct and Indirect, and the recording and collection of costs under these headings can be facilitated by the use of different colours for the various requisitions and Time Sheets. Whilst in special cases costs other than material and labour are sometimes treated as Direct, these two are the most important items. It is the duty of the section dealing with the collection and the distribution of costs to record all such costs on a form—see Fig. 29—showing in the vertical left-hand column the various types of costs, and in the top horizontal column the cost positions. The items given in Fig. 29 are only an example to facilitate understanding, and the form there shown is not to be regarded as a scheme for general use. Circumstances in actual practice vary so much that it is necessary to consider each case separately. Special care is needed to ensure that no costs are booked in more than one place on this form. This is of particular importance with material entries, but possibilities of error can be minimised by requiring that all material, irrespective of type and the condition in which it enters the factory, is booked by the stores prior to issue to the shops, and only given out against presentation of requisitions. In this way the use of invoices from which to enter particulars on the form is avoided. There are cases, however, where, owing to the great weight and bulk of certain parts, it is more economical for them to be delivered straight to the shops, instead of physically passing them through the stores; but even here the actual booking of the material must be done by

the storekeeper in conjunction with the shop-foreman, who will sign a requisition for its receipt at the same time.

The type of form shown is chosen primarily to make clear the principles involved; in actual practice, however, the information it contains is often expanded and given in detail in card indexes or card filing systems.

Fig. 29 shows the types of costs divided as to Direct Costs (rows 1-3), and Indirect Costs (rows 4-18). The latter are again sub-divided as to those items for which the supporting statements—i.e. requisitions, invoices, time sheets, etc.—exist, termed Real Indirect Costs (rows 4-14), and those for which no such supporting statements in the accepted sense exist, simply because they are not real expenditures, termed therefore Calculated Indirect Costs (rows 15-18). It is, however, necessary to put them into the total cost because they represent necessary provisions as will be seen :—

(15) *Depreciation*. Provides a replacement for the wear and tear and obsolescence of the whole plant.

(16) *Interest*. This represents the amount which would be earned by the long-term capital locked up in fixed assets, e.g., buildings, plant, machinery, etc., at the rate of interest for such money in the capital market, together with the amount which would be earned by the short-term capital, generally used as working capital, at the short-term money rate then ruling.

(17) *Employer's Drawings*. This represents, in the case of a business where the employer is the sole owner, the amount drawn for salary as distinct from the amount taken out in profit. This would correspond to the salary paid to, say, a managing director or a general manager, or both, in a joint stock company.

(18) *Risks*. This represents the amount set aside as reserve to cover those risks which it is impossible or uneconomical to cover by insurance, and includes such items as pilfering, faults in design, material losses due to change in fashion, bad or doubtful debts, machine breakdowns, etc.

ASSESSING DEPRECIATION

A considerable amount of attention could, of course, be given to Calculated Indirect Costs, but it will be sufficient to

→ POSITIONS OF COSTS.		TOTAL AMOUNTS.	MANUFACTURE.				TRADE.	
↓ TYPES OF COSTS.	STORES AND STOCKS.		PRODUCTION WORKSHOPS.	AUXILIARY WORKSHOPS.	FACTORY ADMINISTRATION.	BUYING.	SELLING.	COMMERCIAL ADMINISTRATION.
DIRECT COSTS.	1. DIRECT MATERIAL.							
	2. DIRECT WAGES							
	3. OTHER DIRECT COSTS.							
INDIRECT COSTS.	4. INDIRECT MATERIAL.							
	5. INDIRECT WAGES.							
	6. SALARIES.							
	7. INSURANCES.							
	8. ELECTRIC POWER AND LIGHT.							
	9. GAS AND WATER SUPPLIES ETC.							
	10. REJECTS.							
	11. ADVERTISING.							
	12. CARRIAGE IN AND OUT.							
	13. PATENTS ETC.							
	14. SUNDRIES.							
	15. DEPRECIATION.							
	16. INTERESTS.							
	17. EMPLOYER'S DRAWINGS.							
	18. RISKS.							
	19. SUM OF ROWS 4-18.							
CALCULATED INDIRECT COSTS.		THE FIGURES IN THIS COLUMN ARE OBTAINED FROM THE BOOK - KEEPING LEDGERS.						

FIG 29. COST COLLECTION FORM.

emphasise here only one point—Depreciation. For the purpose of costing, this is often quite a different thing from the items appearing under this heading in the balance sheet and profit and loss accounts. For costing purposes a conventional or generally accepted percentage that may be too high or too low—better too high than too low—is not good enough. Some real attempt must be made to assess it on the basis of real wear and tear, modified by the rate at which the plant becomes obsolete.

Such an assessed or estimated percentage allowance for depreciation will depend on the type of plant, the use to which it is put, the working time, and the amount of maintenance it receives. Only the maintenance engineer responsible for plant upkeep, and having the necessary knowledge and experience, can say with reasonable accuracy what percentage should be taken in any individual case. Such guidance on this subject as has been published in the technical and commercial press specifies percentages only for average conditions, and can therefore be used only when actual conditions approximate to average.

ALLOCATION OF COSTS

The figures for each type of costs are entered from the various book-keepers' ledgers, under the column headed Total Amounts (Fig. 29), and distributed to the different cost positions in such a manner that each position receives that part of the Total which is expended in it or for it. Where this is not possible, or can be obtained only with difficulty, the allocation of the various types of costs to the various positions is carried out on an agreed basis of distribution. This is generally supplied in the form of a key giving the percentage that every position should bear.

The sum for each cost position can then be obtained by adding the figures in the appropriate vertical columns and entering the result in row 19.

The cost positions are divided into two groups, one comprising those items which concern the handling of the product, *e.g.*, stores and stocks, production workshops, and selling; the other comprising administrative and buying services which have no direct connection with the product, and must therefore be

considered as an indirect charge. In order to arrive at the final cost summation used in the calculation of selling prices of individual products, it is necessary first to distribute the second of these groups over the first, so that each of the former bears a just and fair proportion of the latter, having due regard to the facilities afforded, and also in such a way that the total cost is fully recovered. The amounts so obtained under each position can be related to the corresponding amount under the direct cost summation, and be expressed either as a percentage thereon, such percentage being used in calculating the total costs of individual orders; or, in those cases where it is possible to give quantitative figures for the output of the various direct cost positions, as a cost per unit of output.

As an example, let us suppose that the total cost of operating the stores and stock department is £10,000 in a certain month, *i.e.*, 2,400,000*d.* per month, and the stores delivered to the production workshop in the same period 24,000,000 lb. of material, then the cost of storage and transport associated with the stock and store department would be equal to 1*d.* for every 10 lb.

Again assuming the indirect cost of production in a production department to be £750, with a direct wage bill for the same period of £500, then the percentage of indirect to direct cost is

$$\frac{750 \times 100}{500} = 150 \text{ per cent.}$$

or, if wages are expressed in time, *i.e.*, instead of £500, let us say 9,000 hours, then the indirect cost can be expressed as

$$\frac{750 \times 20 \times 12}{9000} = 20*d.*/hr.$$

As a further example let us suppose that cost of production in a particular period is £25,000, and the corresponding cost of selling £2000, then the total cost prior to sale will be £27,000, so, in order to arrive at the selling price we must add

$$\frac{2000 \times 100}{25000} = 8 \text{ per cent. to the production costs.}$$

We have now all the fundamental data necessary to calculate the costs of each order placed in the factory, and the com-

position of this cost from the point where the material is received up to the point where the finished product is sold. This can perhaps be more clearly seen from the table given below, which is in effect an extension of the equation given at the beginning of this book.

Direct Material Costs

+

Indirect Material Costs

arising from storage and transport in stores, and between stores and workshops and in the factory generally

+

Direct Labour Costs (Direct Wages)

+

Indirect Labour Costs

incurred by the workshops and for factory administration, etc.

+

Other Direct Costs

gives the

Total Production Costs

to which must now be added

Direct Cost of Selling

+

Indirect Cost of Selling

incurred in purchasing and administration, etc., to give the complete

Total Cost

Although the foregoing gives a complete picture of the composition of unit costs, it is not necessarily the only correct or most simple one. It is abbreviated in some respects and enlarged in others from schemes in actual operation, and is given as an approximation to the general case.

The particular scheme to use in a given case will depend upon the type of manufacture, *i.e.*, either mass or serial or single production; upon the type and branch of industry concerned; and upon other circumstances.

In some cases it may not be necessary to make so marked a distinction, or indeed any distinction at all, between indirect and direct costs; for instance, in the case of the manufacture of a single, uniform, and specialised product. In others it might be necessary to increase or reduce the numbers of cost positions, distinguishing, for example, between such departments as design and production.

Only the fundamental principles are illustrated by the examples given, and it must be left to the reader to select the details best suited to the business he is considering, and to make his own choice in regard to abbreviation and extension.

STANDARD OR NORMAL COSTS

Up to this point, we have examined the practice of cost and works accountancy only in so far as it treats of *past* performance. We have seen the connection between book-keeping and the collection and distribution of costs, and how the latter is used in the investigation of the undertaking and in the determination of overhead costs. It only remains to state the limitations of this system from the standpoint of cost control. Book-keeping treats, as we have seen, with *time past*, and collection and distribution with *past orders*; whilst it might be very satisfying, at first sight, to confirm that the summation of the profits on all the individual job orders is equal to the total profit shown in the profit and loss account, this is a satisfaction that does not justify the work and expenditure of obtaining it, and is of no considerable benefit, in itself, to the undertaking. From the control standpoint—that is, with the possibility of increasing efficiency and reducing cost—it must be remembered that figures of the past are being dealt with, and any comparison made as between one period and another, to be of any value, would have to be made in the light of the particular conditions ruling in both of the two cases.

A sounder method therefore will be to compare actual costs with a standard or normal cost, *i.e.*, to compare *what is*, not with *what has been*, but with *what ought to be*. This brings us to the important subject of normal or standard costing, and here our attention will be focused on the future. Collection and distribution of costs will be used only as a guide to establish new standards based on the experience of the past.

As in all estimates of future performance cost figures must be based on the estimated level of production which it is anticipated will be attained, it is necessary now to examine closely the relations of indirect to direct costs under varying conditions of output. For this purpose the following ratio will be considered—

$$\frac{\text{Indirect Cost (numerator)}}{\text{Direct Cost (denominator)}}$$

The value of this ratio will depend on the volume of work going through the particular "cost position"—say a department—in the period under consideration. Whatever this volume of production may be, it is safe to assume that the direct cost incurred will be directly proportional to it. The corresponding indirect costs, on the other hand, will not, if taken as a whole, follow any such mathematical relation. Certain of these costs, it is true, will vary directly with changes in the volume of production, but others will be quite independent, and still others will be more or less proportional to the level of output. From this it will be appreciated that the incidence of the non-variable and semi-variable portions of the indirect cost will be greater at low than at high levels of production, and the ratio will increase as the output falls.

A fall in production as a result of a fall in sales is therefore accompanied by an increase in the ratio of indirect to direct costs, and consequently by a rise in the total cost, and the first impulse would be to increase the selling price to counterbalance the rise in costs. This policy would, however, only make matters worse; for if it were impossible to avoid a fall in sales consequent on a drop in the market demand at the lower price, it would be more difficult still if the selling price were increased still further.

It must therefore be the utmost endeavour of all concerned to take steps to ensure that the plant is operated as closely as possible at the normal capacity for which it was designed. To operate either below or above this normal capacity is to involve losses.

Having regard to this, it will be readily appreciated that the knowledge of the actual costs that were incurred under conditions ruling at the time a particular job order was

executed is of much less importance than a knowledge of what the costs would be under a *normal* level of production.

It is not easy to find the ratio corresponding to normal capacity, and attempts to do so by mathematical means have so far failed. Indeed, it is very doubtful if the future will bring any success in this direction, as the number of unknown variables arising out of different influences at work make mathematical treatment extremely difficult, if not impossible.

In the absence of any more accurate method, estimates have to be made, based often on past experience and sound judgment. These estimates can be, and are, revised in the light of further experience, and can be closely controlled by accurate statistics. Such figures as are used are of course applicable only in the particular plant for which they have been developed, and can on no account be translated from one undertaking to another. Their use as a rough guide is not out of the question, but any information so taken should be thoroughly tested against actual conditions prior to application in new circumstances.

This brings us to another important branch of cost accounting practice—cost estimating.

COST ESTIMATING

In estimating job costs, recourse is had to past costs of the same or similar jobs, and due allowance is made for any changes that have taken place since the product was last made and any further changes that may arise before the new job is executed.

Material costs obtained, as has already been seen, from invoices, with additions for packing, freight, and other such charges, may require to be modified to take account of fluctuation in market prices before they can be used in the estimate.

In a time of fluctuating commodity prices, it has been the authors' experience that it is better to select the market price ruling at the time rather than the previous invoice figure. With relatively stable price levels this is not so important, and the saving from minor adjustments would outweigh the additional clerical cost of making them.

Wage costs, also, will have to be modified to cover changes

in wage rates, which might be the result of wage agreements already made or contemplated.

EXAMINATION OF ITEMS

The work entailed in arriving at the total estimated cost of production is always well worth the trouble, even if the result indicates no significant change in the job costs; for an opportunity is thus afforded to examine critically every item forming the cost and to take steps where possible to make economies.

First, the possible margin of profit is checked by comparison of the cost of production with the selling price. If this is too low, methods of production can be scrutinised, processes changed, sequence of operations altered, and even a revision of design made. Possibilities of purchasing all or some of the parts comprising the product from outside, or of having certain operations performed in another factory, can be critically examined. In this connection it should be stressed that not every change that appears at first sight desirable or even economical should necessarily be introduced. For example, it might appear cheaper to have a part made outside the factory if the internal cost is higher than that quoted by the outside manufacturer, but one must be well assured that the outside product will not only be up to the same standard of quality, but will be delivered at the time required. Further, one must not lose sight of the fact that work sent to outside manufacturers reduces the loading of the factory as a whole, and may affect some departments more than others. As has already been seen, the effect of a reduction in the volume of the production is to increase the ratio of indirect to direct costs, and this can only result in a raising of the costs of the remaining jobs.

Similarly, decisions to change the methods of manufacture which involve a transfer of all or some operations from one department or cost position to another department or cost position must have regard to this effect of the level of production on the total production cost. For example, let us suppose that a component originally swaged in the forge is now to be made of sheet and rolled-iron sections necessitating welding instead of smith work. This will mean transferring

the operation from the forge to the welding department, and before any final decision is taken it is important to know not only the saving in material and direct labour cost, but also the gain to the welding section consequent on the increased amount of work in that section, and the loss to the forging shop occasioned by the lower volume of production caused by the transfer. In all cases the advantages must be weighed against the disadvantages before a final decision is made.

The value of this work cannot be measured solely by the possibilities indicated to reduce production costs. The training which such investigations provide is also of the greatest importance in the development of the "economic sense."

Heretofore only estimates of individual job order costs have been considered, and now attention must be turned to estimates for the performance of the undertaking as a whole.

Whilst it would be possible to get an idea of what this performance would be from a summation of detailed cost estimates of all individual job orders, this would involve an immense amount of clerical work entirely unjustified by the results obtained. It will be more convenient, and for all practical purposes sufficiently accurate, to take a summation of the costs of all the chief individual job orders, and this is provided in convenient form by the book-keeping records which will now be considered.

COMPARISON OF ACCOUNTS

Another check on the operation of the undertaking as a whole, and one that until comparatively recently was the only one, and is still to-day the normal indication, is provided by the book-keeping side of accountancy. It is often found, however, that the classification of accounts in the book-keeping ledgers does not correspond exactly with the types of accounts used by the section that carries out the collection and distribution of costs. This leads to double work and inconsistent results, with much waste of time in clearing up discrepancies, and ought to be avoided by drawing up a plan of accounts so suited to the undertaking concerned that the fundamental needs of both book-keeping and cost-collection are recognised. The accuracy required in book-keeping is

greater than that needed in cost-collection; this, however, does not detract from the value of a common plan of accounts. But here, for the purpose of judging the performance of the undertaking as a whole, it is necessary to deal only with such records as are kept in the book-keeping ledgers and maintained by the infallible double-entry system. These records culminate in the balance sheet and profit and loss accounts. These important financial statements can be presented either in an abbreviated form, in which a large number of the individual ledger accounts are merged under a few main headings, or alternatively presented with each individual account shown.

It is with the latter method of presentation that we are here concerned. From these financial statements the profit or loss made by the undertaking during the period covered may be found; but more than that may be learned.

THE BALANCE SHEET

On the right-hand side of the balance sheet are found the assets—*i.e.*, all property and possessions—on the left, liabilities—*i.e.*, the debts of the undertaking; and the difference between them—neglecting for the moment any recorded profit or loss—represents capital. At the time when the balance sheet is first drawn up, this capital has no reality. Even now after a period of manufacturing and trading it is merely a book figure representing the difference between assets and liabilities, all the original capital having been spent or invested in the different things which form the property and possessions of the undertaking: buildings, machines, materials, etc. It is therefore impossible to withdraw the capital from the undertaking. It is questionable even whether the property, if sold, will realise sufficient cash to enable the capital to be repaid. Much will depend on the nature of the assets, and whether or not they are capable of being readily realised in cash, or, as it is termed, whether they are “liquid” or not. This aspect of the “liquid” nature of the assets is very important, and one of the first investigations made in checking the balance sheet is the determination of the possibility of liquidating or realising the various assets.

A further point of the investigation is the return on the invested capital, *i.e.*, the ratio of turnover to total invested capital. For, as has already been mentioned in discussing the uninterrupted flow of work in the analysis of work and time, all time spent by raw-material and semi-finished parts in the stores, in unnecessary transport, in standing plant and machinery, etc., is time in which part of the capital is idle and giving no return, and is therefore a loss reflected in lower total turnover, *i.e.*, in the numerator of the ratio $\frac{\text{turnover}}{\text{capital}}$. It will also be appreciated that this ratio will be reduced by increasing the denominator or capital in use. Care must accordingly be taken to keep the amount of invested capital as far as possible at that figure which will not endanger the continuation of the undertaking. Intelligent use of this ratio should therefore give a warning against incautious expansion in the purchase of new machinery, and encourage a thorough investigation of the economic consequence of any proposed new capital expenditure.

Other and similar ratios of balance-sheet figures can be used in judging the economic state of the undertaking, but the examples given may be sufficient to show the importance of the book-keeping section and accountancy in the financial control of the undertaking, by providing a test of the success or failure of business policy, and an analysis of the location and causes of error.

THE BUDGET

Lastly, some words about the budget may be added. All information as to past performance collected in the various departments should be used to draw up a plan or budget for the future. This would show how and where the various amounts should be spent. For example, a purchasing, a production, and a sales plan would be drawn up utilising past figures only as a guide, and modifying them to meet the probable changes of circumstances. It will be seen therefore that there is an element of prophecy as well as a declaration of intention in the budget plan. Since nothing is so uncertain as prophecy, it is not surprising that it is seldom possible to keep strictly to the

figures of these plans. They should be considered only as a sign-post indicating the direction in which it seems advisable to work, and not, as is sometimes the case, as strict instructions which must be carried out. At least, if it is thought right to give to the figures of the budget plans the character of instructions, this aspect should be modified by giving limits of permissible variations; but even such limits are sometimes not wide enough, and it will often be necessary to change the figures afterwards, because of the difficulty or impossibility of forecasting, with sufficient accuracy, the conditions that actually occur.

This word of caution on the inadvisability of a too strict handling of the budget should not be regarded as casting doubt, in any way, on the importance and value of budgetary control.

To recapitulate, it has been seen, first, how industrial accountancy gives a true reflection or image of the cycle of values in an undertaking, and how this is made possible only by regarding the matter as a coherent whole, from the point of view of time and performance, and past and future, a four-fold standard.

Next the collection and distribution of costs were dealt with, and the threefold order of costs—types, positions, and bearers of costs—was developed on the cost collection form and the schemes of allocation and calculation were indicated.

The use of a different valuation of costs for the same item in different sections of industrial accounting was discussed, and stress was laid upon the part played by changes in the volume of output on total production cost.

Book-keeping was recognised as providing the means of judging the undertaking as a whole, and the significance of budgeting as a guide for the future direction of a business was pointed out,

This survey may suffice to show the close connection existing between industrial accounting and the various branches of management. Only a system of cost accounting based upon such principles as have here been indicated can give a true picture of the success or failure of the management methods adopted.

PROFIT AND SUCCESS

It is admittedly vital to the continuance of an industrial concern that the profit and loss account shall be satisfactory, that is to say, that it shall reveal and prove that over the period to which it refers, operations as a whole have resulted in a profit. This, in itself, however, is not a guarantee that all is well with the business.

It must be remembered that although every possible care must be and usually is taken that the profit and loss account and balance sheet shall give an accurate reflection of the result of a year's work and the present position, and that checks are applied to ensure this, yet certain assumptions are made in compiling it that profoundly affect the result, and that it is therefore by no means an absolute or complete statement of fact.

Moreover, as has been indicated in preceding pages, there are many factors, features, and tendencies in a concern that contribute to the result; but their influence, which may be good or bad, cannot be discovered, still less discussed from the figures in these statements.

If, however, a complete and accurate knowledge of affairs is to be obtained (and future developments cannot be intelligently and usefully planned unless all the relevant facts are known), their hidden influence must be brought to the surface.

To illustrate the first statement it is only necessary to recall that it is not unknown for a business to present apparently satisfactory annual accounts, and in three months go into liquidation, notwithstanding that the balance sheet has contained no error.

In illustration of the second, how can one tell from the profit and loss account just what has been the result of the expenditure in improving the lighting, heating and ventilation in the factory; of the assistance given to welfare work and social service; of the pension scheme? It is not possible, as a rule, from the annual statements alone, to discover with certainty whether a special and expensive advertising campaign has succeeded or not, or even whether the new manager who came only a year ago is making good. Indeed, with regard to the last-mentioned feature, the annual statement may appear less favourable than a year ago, and yet the real conditions be very considerably better.

And so it is not sufficient to examine and discuss the profit and loss account and balance sheet in the usual way; it is necessary to have further and fuller information, and the information already available must be scrutinised. This further examination is conducted in three steps, and these three steps can be taken simultaneously; in any case their results must be presented at the same time as the accounts. The nature of these is indicated below :—

REPORTS

(1) Auditor's Report (on Figures).—All figures in the balance sheet and profit and loss account are checked by comparison with the book-keeping ledgers, and the ledger entries in turn with the supporting statements of invoices, requisitions, and time sheets, and at the same time it is confirmed that the correct accounts have been credited or debited, and the rules of the double-entry system observed.

(2) Report on Facts.—The figures of the balance sheet and profit and loss account are examined to determine whether the figures shown and their supporting statements really represent actual working conditions and allow adequately for future developments. An examination of this nature should, for example, lead to such important questions as :—

(a) Is the valuation of raw material stock satisfactory and conservative in view of market changes and tendencies, or should it be modified ?

(b) In the same way, is the stock of the finished product a live and satisfactory one, or has some portion of it become unsaleable owing to changes in public taste, or to greater attractions of competitive products ? If the former, is the valuation conservative and certain of realisation, and if the latter, has proper reservation been made ?

(c) Is the rate of depreciation on buildings, plant, and machinery adequate to the working conditions ?

The answers to all these and similar questions should be, and usually are, given in a report descriptive of the balance sheet and the profit and loss accounts. This is often regarded as outside the province of the accountant certifying the books

of the company, who, it is generally held, should be concerned only with the formal check (*i.e.*, report on figures). And indeed he would be equipped to make such a report only if he possessed, in addition to his knowledge of book-keeping, a wide understanding and experience of the particular problems of management in the industry in question.

(3) Report on Management.—This report should contain some further statistics that are important to the continued satisfactory operation of the company, and throw some light both on the policy adopted and on the quality and character of the management. For instance, labour turnover, which, though sometimes not recognised as such, is an expense, may merely show the effect of the fluctuation of sales ; but it may indicate the temper of the workers ; accidents and health statistics throw light on a matter which, because it affects the well-being of the workers, affects also the prosperity of the company. The report should also deal with those factors which, though they cannot be represented in figures, are nevertheless of vital importance to a concern, and should be known so that its condition may be accurately judged and its future policy be rightly planned. For example, the relations of the staff to one another and to the company ; the relations existing between the company and its operatives and between the staff and the operatives ; the relations between the company and its customers, and the views of the latter concerning the quality of its products, the punctuality of the deliveries and the service given.

These are perhaps the most important features to be reviewed and considered in this report, but there are others that should not be overlooked.

Any work that has been done in improving the plant lay-out or in modernising the plant, and the effect of these changes on production ; the situation with regard to supplies and cost of raw materials ; the possibility of extension or restriction of sales, and the trend as shown by the past year's work are all matters that can properly be dealt with at this time. It may or may not be desirable to review the company's selling policy in its relation to the degree of activity of the plant during the last year.

It will be appreciated that if the matters dealt with in this

report are treated frankly, it will give indications as to the manner in which the concern is managed. It will criticise, and, if the criticism is to be of real value, it will be objective criticism. This suggests that it would be more valuable if made by some competent person who is quite independent of the concern, just as the financial accounts are audited by an independent accountant.

An independent report of this kind would not only be invaluable to the board of directors, but would almost certainly be of considerable assistance to the manager or managing director himself.

After all, these things represent the life and spirit of the undertaking, and are much more important than the financial results of a single year's working. A year's working though unsatisfactory as to figures may be accidental and relatively not of first-rate importance. Whether this is so or not will be shown by this management report, and if this latter reveals anything wrong in the matters mentioned, it means that the concern is suffering from a disease which, unless it is promptly treated, will lead to further bad results, ending, it may be, in disaster.

CHAPTER VII

CONCLUSION

THE declared purpose of all that has gone before has been to give a clear and understandable idea of the principles of management, and to deal with them quite generally. On the other hand, perhaps, the reader may be interested only in a specific case; and indeed the purpose of his reading may have been to see if he could obtain guidance and assistance in the application of the principles of the new management to an existing undertaking, which in his view requires modernising, or at any rate overhauling; or perhaps his reading of this book has given rise to a desire to improve the management of the concern he is controlling. It has been repeatedly and insistently stated that the management methods and means must be suited, and in proportion, to the ends they serve, and must be designed with those ends in view; that, in other words, there is no specific cure for all cases, or even for a large range of cases. It follows that for the present authors to attempt to give definite instructions applicable to any case that might be in the reader's mind would be like the blind attempting to lead the not-so-blind. Nevertheless, it may be possible to give some general indications how to approach such a task.

The first matter to decide is who is to make or direct the making of the preliminary investigation, if such be necessary, and who is to carry out the subsequent work shown to be necessary.

It can be said at once that the best arrangement, if it is feasible, is for the general manager to take active control of this himself, because :—

(1) He already knows the organisation and the work, and can dispense with some, but not all, of the preliminary investigations.

(2) He already knows the reasons that have led him to decide

that reorganisation or modernisation is necessary, and if these are urgent, can adopt some immediate measures until the complete plan has been decided upon. Further—and this is most important:—

(3) It requires a firm but gentle hand, patience, and certain freedom from routine work. Moreover, if the work is done by the general manager, he can carry it out in stages, and somewhat slowly, avoiding excessive disturbance likely to cause unrest. It is always a good plan to do work of this kind in steps, with a pause between. Of course, if conditions are very bad and reform is urgently necessary, drastic steps have to be taken, and disturbance is unavoidable.

These remarks apply to the first introduction of the newer methods in an existing works, and to the inquiry that will naturally precede it. It is understood, of course, that subsequently the organisation and methods will be continuously revised or improved to suit changing needs or conditions.

If for any reason the general manager or someone of equal rank and authority is not available, a consultant from outside might be retained for the purpose, and this course also has some advantages of its own.

(1) Being entirely free from other duties, the consultant can concentrate entirely on the work of inquiry, and subsequently on putting into effect the measures considered to be necessary.

A staff employee detailed to this work is always liable to be called upon to undertake other work, either in an emergency or as a matter of convenience, and this is not good for the purpose now in view, and renders concentrated and continuous work difficult, if not impossible. A consultant retained for the purpose will generally have greater prestige in the works than a staff employee, and will therefore exercise greater influence without his decisions being challenged or resented, and this may be very important.

(2) A consultant will be entirely free from departmental or other bias, and will therefore be more likely to find the plain truth, and will also be able to keep in view the balance, symmetry, and harmony of the whole concern. An employee who has a previous history in the undertaking is very likely to have predilections and prejudices which will influence not only his methods of inquiry, but also his judgment of the results.

(3) The consultant, having carried out investigations in many different branches of industry, has come to recognise and to know thoroughly the fundamental and common principles that apply to all cases, and consequently is not likely to pay undue attention to relatively unimportant details. Very often, in applying one of these principles in a particular case, the limits of its application are learned so accurately that in another case, in a quite different trade, one can avoid the mistake of exaggerating it, and yet take it to the limit of its validity. A consultant will recognise at once the more significant sources of waste, will stop them immediately, without going into more detail, and will not make the mistake of spending pounds to save pennies.

(4) The consultant will come to his task with an open mind, free from the prejudice and bias that any one steeped in the knowledge and tradition of the particular business cannot avoid. His view is fresh, and may quite well be usefully novel. This sounds paradoxical, for it amounts to a statement that one who knows nothing of a business has, from that fact, an advantage in reforming it. It must be remembered, however, that "the looker-on sees most of the game," and moreover that the proposals of the consultant will almost certainly be considered and discussed by those who do know the business, and differences of view can be resolved by this means when all the facts are known and clearly stated. Again, the consultant, after all, is not dealing with the technological processes of the manufacture, but with management only, and in this matter his knowledge is probably deeper, and certainly his experience is broader, than that of the staff employee.

The freshness of view referred to above, brought by an outsider, is always valuable. Things that are seen and suffered every day by people in a works are not noticed, and can grow, provided they grow gradually, until they become really serious. Here is an example. A regular visitor to a large works noticed that the ram of a hydraulic accumulator was leaking badly. After seeing it several times covering a period of perhaps three months, and noticing that nothing apparently was done about it, he asked an engineer to make a test to discover how much this leak was costing.

It was then discovered that the cost of the steam to

pump the water in replacement of the leak was £600 per annum!

(5) Lastly, a consultant will be less likely than a staff employee to make the mistake of legislating for the exceptional case, a mistake the latter is peculiarly prone to make, for the reason that an exceptional occurrence may have brought him or his associates trouble; trouble always leaves a deep impression on the mind of a conscientious or timid worker. A consultant would be completely immune from this bias.

The advantages of employing an outside consultant on this kind of work have been dealt with at some length, but this does not mean that this course is recommended either generally or in any particular case. There are both difficulties and dangers about it. It is vital that the consultant employed must know the whole art and science of management, and not be a specialist on some particular function or method; and emphatically not one who has a material interest in some particular method, and will therefore seek to use it without much regard to its applicability in a particular case, and still less with regard to the tradition and policy of the company, and its harmony with the rest of their organisation.

Management must be treated as a coherent whole, and no particular phase or feature of it be exaggerated beyond the level of its relative importance. When a consultant has been selected, he must agree, before appointment, to submit to proper control.

It has been said at the beginning, and may be repeated here, that this work—revising, organising, modernising—call it what you will, is work for the general manager. It is arrears of work that he or somebody in his place ought to have done steadily and continuously in past years, instead of rather rapidly in the next few months; and it follows, therefore, that he is peculiarly fitted to do it, if he can free himself sufficiently to give it the necessary concentrated and continuous attention. Even if that is not the case, and a consultant is employed, the concentrated and continuous attention of the general manager is, in some measure, necessary, because the consultant himself will require support, advice, information, and perhaps restraint. It is never wise, and may be exceedingly foolish and dangerous,

to delegate to a consultant any of the powers and duties of a general manager.

Returning now to the original postulate of a reader, controlling an undertaking, who feels that his organisation needs overhauling.

His own conscience, enlightened it may be by the reading of this book, tells him that he does not know enough about its present condition; that lately he has been so much occupied with matters that seemed more urgent that his knowledge has become a little stale. It may be that incidents and occurrences in the daily life of the business indicate that things are not quite as good as they might be.

In such cases a few tests that any general manager will know how to apply will reveal all he wishes to know, and indicate the remedy. For example, let him take some job, say, one where a customer refers to delay in delivery, or where an unfavourable cost report has been received, or anything else reflecting on the organisation of the concern, and let him trace that job right back to its beginnings and through all its details, neglecting no aspect or feature of it, whether relevant to the point that drew the matter to his attention or not. The amount of information that he will obtain from a single exhaustively conducted inquiry of this kind will surprise him. It will take him into every department of the organisation and management and most of the departments of the works. He will also be surprised at the number of things that he will find that have been done wrongly. He need not be too disturbed about this, but let him carefully sift out and note for future reference the important ones, and forget the rest.

He should not make such an inquiry an occasion for "raising hell all round" (for, after all, the responsibility is his own), but should conduct it in a calm, inquiring, and judicial manner.

A few such inquiries will give him a very clear idea of how matters stand, and will probably indicate a line of action. It may be that he will decide that a complete and thorough reconsideration is desirable, and will wonder where to start the investigation that will be necessary even should he be the general manager, and much more so if he be an outside consultant. No important change of any kind should be entered upon until this complete study has been made, a new

plan drawn up, and all the possible reactions of any proposed change considered.

A good way to start the study is to send for a list of the staff, and inquire in detail into the position and the duties of each member of it. If there is a chart or plan of the organisation, it should be examined, and compared with what is found as the result of inquiry. If there be no chart it will be worth while to prepare one. Any overlapping of duties should be noted and the reason for it (if any) also noted. Nobody should work in a water-tight compartment, but there should not be wasteful overlapping or duplication of work. There is very often a tendency for several people to do the same thing, or to have several systems of collecting the same information that is useful or necessary to all of them. This should be done once for all, but done in such a way that the needs of each individual are satisfied.

Then the methods of payment and the actual salary- and wage-list should be examined. The methods of payment—day-work, piece-work, bonus system—should be carefully tested to see if their several objects are being achieved. Reference has already been made to the possibility of special methods of payment becoming inoperative because of faulty rate fixing, or of conditions changing after rates are fixed without a corresponding revision of rates.

This will lead naturally to an examination of the methods of dealing with materials. The buying of them. Are they always bought from the same suppliers? Why? Has the market price been, and is it, regularly checked? It may be worth while watching, in detail, the manner in which a few purchases are made, following the material into the works, and finding out from the evidence of one's own senses whether it is satisfactory or not. The store-keeping should also be examined in detail; the manner in which the material is examined and received, kept and issued; the theoretical and actual stock levels should be compared with the time necessary to obtain fresh supplies on the one hand, and the manufacturing time cycle on the other. Rough-and-ready calculations of the values of stocks and of work in progress will indicate what amount of capital that could possibly be better used is demobilised in this way. On the other hand, the reverse condition

may be found, and it may be discovered that larger stocks would avoid manufacturing delays. The examination, packing, and despatching of finished material must be considered, and here also, in some cases, the stocks of finished work may be important. Whilst at this point, compare actual deliveries with deliveries promised; this may lead to a study of the order system. How orders are received; how issued for execution, and how long this part of the process takes. Whether orders as received invariably give sufficient information to proceed; if not, how further information is obtained and how long it takes; whether the customer knows precisely what information is required. Is there an order form setting out all this information in a convenient manner?

Who makes delivery promises, and how does he know how much time will be necessary? Is he, perhaps, to be safe quoting a long delivery period, and thus losing business? Or is he too optimistic or too anxious to please, and quoting dates that are habitually broken?

Then the accountancy should be examined, the invoicing of goods, and the collection of accounts; the amount of money outstanding; the occurrence of bad debts; the costing system should be investigated, both the method and the result, in order to determine whether the concern has made and is making profits uniformly, or whether there are some unprofitable lines, and the reason for them; and whether all possible means of reducing costs have been considered.

Inquiries should be made as to stocks of work in progress, the length of manufacturing cycle time, and as to the manner in which delivery promises are kept; and the results may lead him to consider improving the progress planning methods.

In any case, a person with an insatiable curiosity as to how things are done, and why, will collect a lot of information, see innumerable possibilities of improvement, and last, but certainly not least, stimulate other people not only to fresh effort, but to fresh thought. This examination is to be made in the light of what has been said in Chapter II.

As described, it represents one way of attacking the problem, but there may be others, and some of them more suitable to the case in hand.

Even if the result of the investigation is that it is found

unnecessary to take any important action—a very unlikely conclusion—the scrutiny will have been very beneficial. It will have provided information, and stimulated everybody, and if it shows that all is well, everybody will “sleep better o’ nights.”

This brings us to the end of the first part of the book—that is, the enunciation of the principles of management and a statement of how they are related.

It has been stated that the central and fundamental idea is leadership, and that everything must be subject to what is most helpful to, and harmonious with, the central idea.

Although the term “Scientific Management” has been disapproved, it has been shown that use is made of data and information derived from scientific investigation, and to this extent management may be said to be a science; on the other hand, it has been pointed out beyond any possibility of misunderstanding that it can only be applied successfully by one who is specially adapted for it by character and temperament, and by long training and practice, and it is therefore an art. Since its aims are to give service and benefit both to the whole of humanity, and to that small portion of it that falls under its immediate influence, it may well provide any man with an opportunity of satisfying his loftiest aspirations.

PART II

EXAMPLES AND APPLICATION

INTRODUCTION

THE examples given in the following pages are drawn from the actual experience of the authors, who in each case occupied a position of responsibility in connection with the organisation furnishing the example.

The selection has been made primarily to illustrate the principles outlined in Part I of this book, and to make quite clear to the reader the methods of investigation recommended. But, inasmuch as the examples are applicable to industry in general, they will serve a wider purpose.

In order that this wider purpose may be fully achieved, the use of technical terms has been avoided as far as possible, and, where their employment was unavoidable, explanations in non-technical language have been added.

THREE PROBLEMS OF ORGANISATION

It is often possible to learn valuable lessons from one's own or other people's failures when they are studied for this purpose. The first two cases given below in narrative form show striking instances of failure of organisation; the third draws attention to a deficiency of organisation that is almost universal.

I

A manufacturer, who was known for his enterprise and progressiveness, was approached by three men, a salesman, a metallurgist, and an engineer, who invited him to use their services in establishing a foundry to manufacture castings for a particular purpose. These castings were intricate and difficult to make successfully, and had to be made with relatively great accuracy in order to avoid excessive machining. The demand for this casting was greater than the possibility of supply, and growing rapidly, and it was certain that a new foundry would have to be built for this special purpose.

The invitation was accepted, and the manufacturer agreed to finance the undertaking, and to provide a site and services (transport, purchasing, costing, clerical, etc.) for the proposed foundry. To the three "promoters" were allotted the spheres of Sales Manager, Works Manager, and Metallurgist respectively, the latter to control the cupola, and to be responsible for delivering metal of the right analysis, and in the right condition, which was more than usually important for this casting. A practical foundry foreman and foreman pattern-maker were added to their number.

The foundry was built and equipped, a sales campaign was carried out successfully, and contracts were entered into with customers for the output of the foundry, as far as it could be estimated.

Castings made from some of the patterns were found to be

quite correct and the customers for these were satisfied. Those made from most of the patterns were not correct and there were many rejections; customers were dissatisfied, and their contracts were cancelled. The faults in the casting were foundry faults, but not metal faults. No metal fault ever occurred.

The first year's work resulted in a serious loss, and the Sales Manager, who was the senior of the three promoters, and the engineer (Works Manager) were removed. Operations were restricted and carried out under control of the metallurgist and the foundry foreman, as joint managers. Work under this regime was still unsatisfactory, and defective castings continued to be made. Further loss was incurred, and the foundry foreman was dismissed. The metallurgist remained as manager, and the best man amongst the moulders was appointed foundry foreman.

Then progress was made, at first slowly and afterwards more rapidly. No radical change was made in procedure, but much greater attention was paid to details in the preparation of the moulds, and from the result one could infer that the lack of this care had been the cause of the trouble.

Rejections both in the foundry and by customers ceased, and it became necessary again to seek further orders. These were not, now, so readily forthcoming, partly because of the previous failures, and partly because the owner, desirous of recouping his losses, insisted on higher prices being quoted.

However, some orders were obtained, and it began to look as though the storm might be weathered, when final disaster came. The largest customer of the foundry was compelled to go into liquidation, and his account became a dead loss. The owner decided to complete existing orders and then stop operations, and for the future to confine himself to his own special line of business, in which he was highly successful. He was a very patient and persevering man, but this mishap was the second he had suffered just at that time, both of them in lines allied to, but entirely different from, his own.

What were the mistakes made?

(1) The most obvious, but not necessarily the most serious, was in choosing the wrong foundry foreman, and in not changing him immediately defective castings began to be made.

(2) The most serious mistake was in allowing the selling to

get out of step with the production—that is, in selling the whole potential output of the foundry before the initial difficulties of production had been overcome. When a new manufacture is first started, whether it be a new product, a new method, or a complete new factory and organisation, troubles and unforeseen difficulties always occur that often result in initial failure to produce, or in the production of defectives. The concern is fortunate if they occur and are discovered at the very outset, and not at some time later. The occurrence of these preliminary troubles is so usual as to seem almost inevitable and unavoidable, and ought therefore to be expected, and, moreover, provided for in the capitalisation. Instead of undertaking to manufacture seven or eight different designs of a difficult casting in this new foundry at once, there should have been undertaken one, or at most two at a time, and others added only when these were satisfactorily in production.

(3) In commencing a manufacture that was well known to be difficult, the precaution of entering it more gradually may now, after the event, be thought to have been an obvious one to take. Had this course been decided upon, the employment of three men of first-class rank would have seemed a heavy burden, and might have been assumed more gradually, other expenses also being arranged on a lower scale.

(4) The last and most costly mistake was in abandoning the enterprise after all the preliminary work had been done, and all, or the most important, of the preliminary difficulties had been overcome, and there was at last a real chance of a profitable outcome. The demand still existed, and all the circumstances that brought the undertaking into being were fully operative and unchanged; thus whilst it was rather natural in the particular circumstances of the moment to stop, it was a mistake, and a costly one.

II

A company engaged in precision manufacturing, and well known for the high quality of its product, contracted with the Government to manufacture a small intricate mechanism in quantities of 20,000 per week. The dimensions and tolerances of every part were given on drawings, and the gauging of the

parts to these limits was the only test to be applied to the product. As this article was entirely different from the normal product of the company, and as, moreover, the company's plant was required for its ordinary business, a new plant was decided upon. This was selected and purchased, and a new building was prepared to receive it

The processes and methods of manufacture were worked out in the most thorough and approved manner; the tools were designed, made, and tested. A system of gauges and an inspection routine were installed that should have made it impossible for a faulty part to leave the factory.

There was inspection at the machines; in some cases it was a percentage (sample) inspection, but in the case of larger pieces each one was gauged as it came off the machine. There was also a central inspection department, where parts rejected at the machines were gauged again. In this section the limit gauges had slightly wider tolerances than those used on the machines; but these tolerances were still narrower than those permitted by the drawings, in order that any small wear of gauges in regular use would not result in the passing of material that had variations greater than the limits allowed.

Manufacture was commenced, and, after a few preliminary difficulties, production gradually increased until it reached the rated figure.

The product delivered was inspected by the Government on its own premises. At first there was a normal number of rejections, considering that manufacture had only just commenced.

The rejections, however, began to increase, and as the inspectors were entitled to refuse to inspect further, and to reject, any batch (1000) in which they had found ten faults, rejections began to be made in 1000 lots, until those returned were almost as numerous as those accepted. Clearly something was seriously wrong. Production was completely stopped, and all work in progress was collected from the shop and set aside for careful re-examination. Gauges were tested and found correct.

Careful inquiry revealed that the whole of this trouble was caused because material, which had been rejected and accumulated from the commencement, awaiting rectification or

final condemnation and defacement, became mixed with newly produced material. The production superintendent, looking for his week's quota, had cast covetous eyes upon them and taken them, either with or without authority. He had distributed them amongst his other production; and it can be seen that 100 defective parts could be so distributed as to ensure the rejection of 10,000 assemblies.

How was the trouble overcome and what was the final result? A sufficient number of the components to make up a batch were carefully gauged, passed, assembled, and delivered. They were inspected and passed. Then several other batches were made up in the same way and submitted, with the same result.

Then production was recommenced, but with a difference. The inspectors were given complete control over any material found defective, and instructed not to release that control unless (a) the material had been rectified, re-gauged, and found correct, or (b) it was judged that final rejection was not justified, or (c) it had been so defaced that it could not be assembled, but only sent to the scrap-heap. They were further authorised and instructed to stop production at any process that had produced a series of faulty parts, until the fault was rectified.

From this time forward no complete batch was ever rejected, and the individual rejections steadily fell until they almost ceased. The total rejections when the work was finished averaged less than one per thousand.

Then attention was turned to the material that had previously been rejected, numbering more than 40,000 assemblies, that had been placed in a special store built for the purpose. These were gauged carefully, and sorted into groups according to the faults found upon them. The body, the principal component, was stamped with a code letter to indicate each fault found on it. Some few had as many as six letters on them, showing that there were six separate faults.

These assemblies were submitted in batches as before, the best—that is, those with fewest faults—first, for special inspection, by agreement with the Government inspectors.

It was known that the Government inspectors had discretion to allow slightly larger tolerances than those specified, and as it turned out, they were willing to use their discretion in this case;

by this time the company had re-established themselves, and their work was known for its reliability to comply with specifications, and, above all, for the honesty of its inspection.

Production gradually increased until it reached 35,000 assemblies per week, and, as already stated, 99·9 per cent. passed inspection. It is seen therefore that most of the 40,000 defectives were afterwards accepted, of course many of them after rectification. The total amount of work scrapped for any cause was remarkably low.

It is clear from this result that all the preparatory work, process and plant design, tools and gauge-making, etc., had been very thoroughly and very well done, and no serious fault of any kind was ever found with it.

The fault was one of organisation—making, or leaving, it possible for the inspectors to be ignored or overruled; when discovered, that fault was thoroughly and effectively cured, and the whole concern learnt a valuable lesson.

III

It is as necessary in office work as in production that any accumulation of work or congestion, either at any place or any time, should be avoided as much as possible; the “flow of work” everywhere should be as continuous and uniform as it can be made consistent with economy.

One of the most notable interruptions of this steady flow of work in the office, and one that also has its reactions in the works, is the annual stocktaking. Where so-called “mixed accounts” still exist, stocktaking, besides checking the company’s books, checks also the book-keeping on the mixed accounts, and makes it possible to divide the balance into two parts, one showing the “stock,” and the other the “result of trading” as far as the stock is concerned. Whether this condition exists or not, it is considered to be necessary, once a year, to check the figures in the company’s books by actual counting, weighing and evaluating all material, work in progress, equipment, and plant.

Thus, whilst the books show, so to speak, a moving picture of the continuous changes that take place in the property of the undertaking, the stocktaking shows an instantaneous photograph at a certain moment, usually the end of the business

year; and it is obtained independently of the books, by physical examination, and thus serves to check the books. This performance falls into two parts: obtaining the figures and evaluating them.

The first part—taking quantities—is a strenuous, time-consuming, and costly business, requiring, and usually carried out during, a cessation of production. In order that it may be thoroughly and properly done, it is necessary that it should be planned and organised carefully beforehand. All those taking part have to be instructed as to what work they are to undertake and be trained for it; be told what principles they must observe, with what accuracy they must work, and what particulars as to quality, dimensions, weight, and condition as regards manufacturing progress (which will all be required for evaluation) must be recorded. The works are generally divided into districts geographically rather than by material concerned, the person selected for each district being, by preference, one who is familiar with it. This arrangement is dependent, however, on the particular circumstances, and in some cases both methods of division of work are used, separately and/or combined.

If the work has to be done whilst production is in progress, care is always taken to reduce the figures, either by calculation or by estimation, to one and the same moment—for example, 12 midnight, December 31st.

For the valuation, conventions have to be observed. Raw materials in a rising market may be (conservatively) valued at cost; in a falling market at the price of the moment, or, more conservatively, a further fall may be allowed for. For work in progress the processes completed will not be valued higher than at cost. In doubtful cases work in progress may be regarded as raw material.

Naturally, to extract the utmost value from such a disturbance, stocktaking should be, and often is, made the occasion for a real clean-up throughout the works.

Every nook and corner, as in the “spring cleaning” of a home, should be cleared; all broken, condemned, and useless material sent to the scrapheap; hidden (intentionally or otherwise) stocks of material, *i.e.*, material requisitioned and taken from stores in excess of requirements and “kept in hand in case

of need," should be returned to the stores; tool equipment be checked over, and, where excessive, reduced to the proper dimensions, etc. In this way stocktaking may be made a precious opportunity to tidy up the works, and this work can be done in anticipation of, and to ease, the real event, and thus the stocktaking serve two purposes.

This process has been dealt with at some length to show the importance with which stocktaking is rightly regarded, even by those who affect to consider it a waste of time and effort, and who talk lightly of the "red tape" connected with it.

But now it is worth while considering whether it is not possible to obtain all the information and advantages of annual stocktaking without the attendant disadvantages. The disadvantages may be recapitulated for emphasis. The two greatest are the interruption of the office-work for a period, with the consequent congestion of accumulated work which has to be dealt with when that period is over, and the interruption to production. The former is likely to be more serious if the staff is designed only to deal with the routine work and not for such an occasion; and it may result not only in a prolonged period of working overtime, with all its disadvantages, but in serious trouble caused by routine work being carried out hastily, or temporarily neglected.

To mitigate this trouble, staffs are sometimes temporarily reinforced, but this is rarely satisfactory. The period of quantity taking is shortened as much as possible, but the accuracy of the results of hasty work is always doubtful.

It would appear that the best way of obtaining all the benefits of annual stocktaking, with possibly greater accuracy than that process usually gives, and of avoiding the attendant disadvantages of disturbance and interruption, is the one known as continuous stocktaking, which has been adopted by a few well-organised factories. This consists of spreading the work of checking the stock lists and inventories by physical stocktaking over the whole year. Continuous stocktaking permits of the use of the figures contained in the books of the company at the close of the business year, without the risk of serious error, and with greater accuracy than is often obtained by the present method.

A relatively small but well-selected and well-trained staff,

under a leader, is permanently and continuously engaged in checking stock lists by physical count, according to a pre-arranged order and routine; this order may be kept secret or announced; in any case, the method permits of unexpected checks being arranged and carried out, in any store or department of the works.

Differences between the accounts and the actual stock are, of course, cleared up as discovered; the arrangement permits of investigation of the reasons for such discrepancies, and of devising the means by which they may be avoided in the future.

The progress planning work, which necessarily requires complete and accurate records of work in progress, is organised and connected with the book-keeping in such a manner that the value of unfinished work can be taken from the corresponding accounts at any moment, and physical stocktaking of this unfinished work is unnecessary. If progress planning is properly carried out, this part of the stock is under perfect control, and work in progress is narrowly limited, in order to secure a continuous flow of work and the quick turnover of capital.

It must be admitted, of course, that continuous stocktaking can only be used where there is a really first-class organisation of stores and accountancy, and this must be guaranteed first. But it gives such a complete and continuous tuning up of the whole of this part of the works organisation that its cost is saved many times over. Moreover, it is very doubtful if this method is any more costly than the old method, but this can always be determined beforehand, in any specific case, from the cost of the annual stocktaking and the estimated cost of the new method.

Continuous stocktaking has the further advantage that it facilitates and increases the accuracy of the monthly intermediate balances, and reduces considerably the work of preparing the final balance.

Experience has shown that wherever this method of checking has been installed carefully and after sufficient preparation, very great advantage has been obtained, and a period of disturbance, trouble, and discord in office and works, more prolonged in the former than in the latter, has been eliminated.

A ROLLING MILL: WORK AND TIME STUDY FOR IMPROVING EQUIPMENT AND PRACTICE

INTRODUCTION

THE following is an extract from a translation of a report made by Dr. O. Cromberg of Düsseldorf, to the Committee of Scientific Management of the Verein Deutscher Eisenhuettenleute published in *Archiv fuer das Eisenhuettenwesen*, 1930, vol. III, March, pp. 597-613. This report has been treated in a more detailed manner than the other reports in Part II of this book because it shows the application of most of the principles given in Part I; further, it was one of the first reports dealing with Iron and Steel Works in Germany, and gave a great impetus to the whole development. It is introduced here because it is suggestive of benefits that may be obtained from similar studies in this country, and not alone in the iron and steel industry.

In order that those not engaged in the iron and steel industry may obtain a clear understanding of this example—for it contains many things of general interest—a brief explanation of the technical terms most frequently used is given.

A rolling mill is a machine consisting of one or more "stands" or "sets" of rolls, disposed one above another. The material that is being rolled passes between the rolls, and since these are firmly held as regards distance apart, which can be adjusted, the material, which is more or less plastic (in this case more, because it is hot) is reduced in cross section, and at the same time increased in length. The rolls may be plain, as for rolling flat material, or profiled to give, in conjunction with one another, desired cross-sections. Any two grooves or profiles that work together to give a particular section are called a pass; a single pair of rolls may have many passes cut in them. The passage of the material between the rolls is also called a "pass."

In the mill described the stands are "two-high" or "three-high." In a two-high stand there are two rolls, one above the

other, and the material passes through in one direction only, since in this case the rolls are running continuously in one direction and are not reversible.

In the three-high stand there are three rolls, and the material can pass between the bottom and middle rolls in one direction, and between the middle and top rolls in the other, being "reduced" and "elongated" at each pass.

A wire rod mill is one that starts with a "billet" as its raw material and produces coils of wire rod, or wire of round, square, or other cross-section; "rods" may subsequently be "drawn"—that is, further reduced in section, and elongated by being pulled in the cold condition through dies.

A billet is a bar usually of roughly square cross-section, and its size is denoted by its cross-section and length, or cross-section and weight, as for example $5\frac{1}{2}$ " square, 410 lb., or $5\frac{1}{2}$ " square \times 4 ft.

As the material begins to emerge from a pass, the end is sometimes caught by a boy (catcher) and inserted into the next pass. Sometimes there is a mechanism that guides it and inserts it into the next pass. This mechanism is called a "repeater."

A. THE TIME STUDY

(1) **Purpose of the Investigation.**—The object of the investigation was fourfold: First, to determine the maximum output which could be obtained from the mill of various classes of wire; secondly, to investigate the possibility of increasing the output, or decreasing the time and cost of the same output; thirdly, to apply the time measurements as a basis for piecework wages; fourthly, to use the time measured as a basis for costing the different types of wire, or "class costing."

(2) **Description of the Plant (Fig. 30).**—The wire rod mill under examination consists of one three-high roughing stand, an intermediate train of two stands, one two-high and one three-high, and a finishing train of nine two-high stands delivering into six coiling drums. Power is supplied by a 3000-h.p. uniflow steam engine, directly coupled to the roughing stand, the other stands being driven by ropes. With the engine running at 100 r.p.m., the intermediate train runs at 243 r.p.m. and the finishing train at 573 r.p.m.

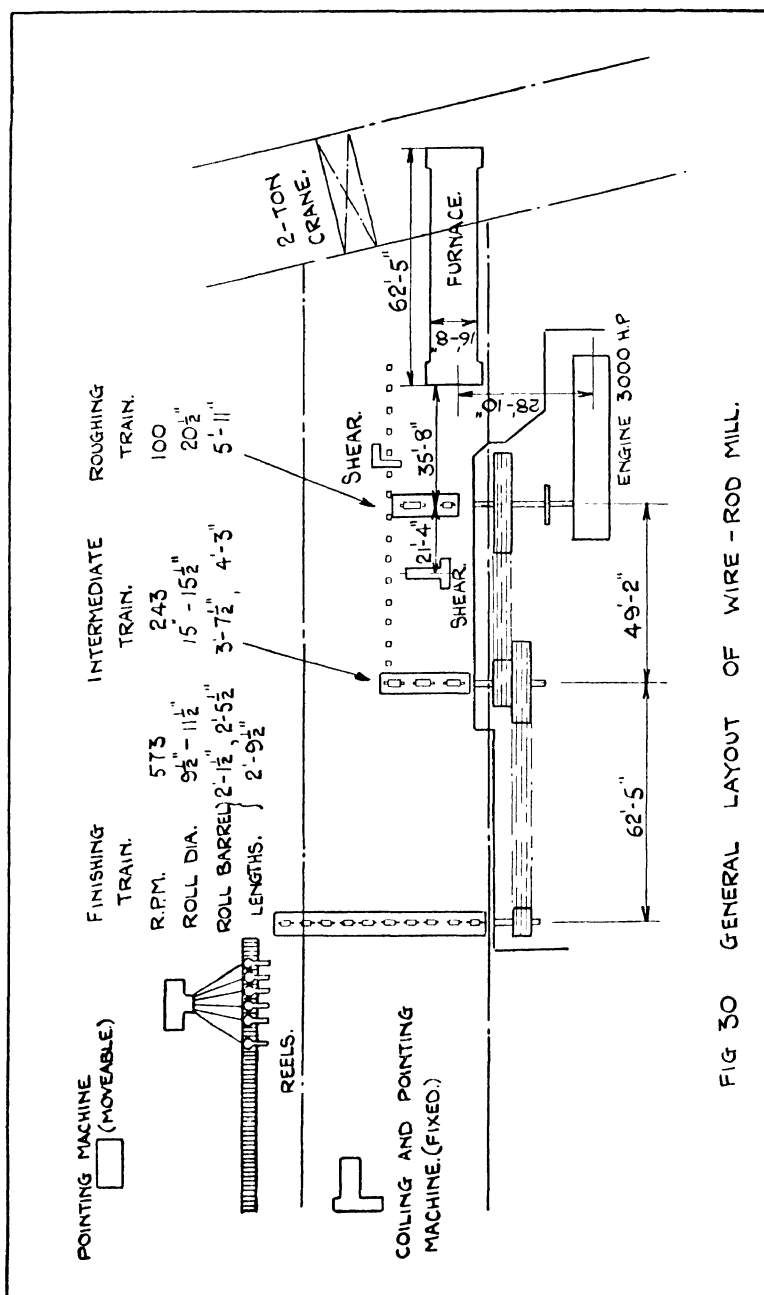


FIG 30 GENERAL LAYOUT OF WIRE-ROD MILL.

The billets are drawn alternately from the right- and left-hand doors of the furnace, which is gas-fired, by means of tongs suspended from an overhead runway, and taken to the roughing train, where they receive ten passes. The bars leave the roughing train on the furnace side, and are cut into three pieces by shears which are situated on the rollers, and then guided in to the intermediate train by repeaters, three to five passes being given, according to the diameter required. The wire is guided by hand on the furnace side of the finishing train, mechanical repeaters being used on the other side. The finished coils are transported from the coiling drums by means of a conveyor, and are taken off by hand on each side for cooling. Wire above 0.2756" diameter required for cold drawing is pointed in one of the two pointing machines, prior to coiling.

(3) Rolling Plan and Pass Distribution.—The mill produces high and low carbon-steel wire from 0.1897" diameter to 0.512" diameter, sections from 0.1968" to 0.3937"; cable wire, boot iron, and mild steel for nut manufacture from 0.3937" \times 0.2165" to 0.709" \times 0.354".

For the general sizes of wire, the billets used are $5\frac{1}{2}$ " square and about 4' long, or 410 lb. in weight; for nut wire, welding rods, and certain special wires the billets are $5\frac{1}{8}$ " square and weigh 360 lb.

During the investigation each size of each quality was observed separately and the times were recorded, because the number of passes and their distribution vary for different sizes and qualities, as explained later (Fig. 31a and 31b).

All products have ten roughing passes, passes 1 to 7 being guided by hand and passes 8 to 10 by "Schopf" repeaters.

Wire from 0.189" to 0.2165" has five passes in the intermediate train, and eleven passes in the finishing train. The wire may be rolled three strands at once from pass 13 in the intermediate train to pass 19 in the finishing train; five strands at once from pass 20 to 25 (*i.e.* three strands from one billet and two strands of the following billet, all being rolled at the same time) and in the twenty-sixth or last pass, six at once (*i.e.* three strands from two billets all being rolled at the same time).

Since pass 13 takes less time than any of the passes from 14

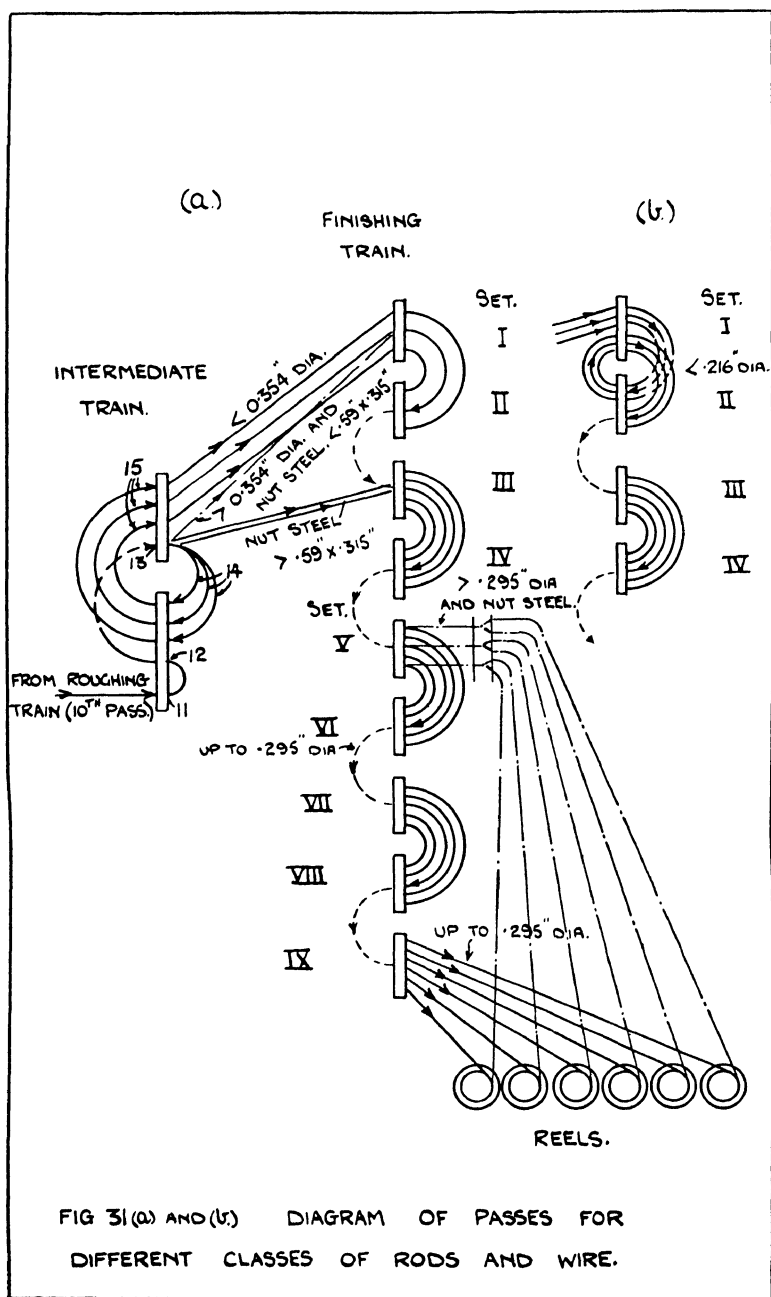


FIG 31 (A) AND (B) DIAGRAM OF PASSES FOR DIFFERENT CLASSES OF RODS AND WIRE.

to 19, triple rolling is possible after shearing. Wire from 0.2205" to 0.295" has five passes in the intermediate train and nine passes in the finishing train.

Wire from 0.2992" to 0.3545" has five passes in the intermediate train and five passes in the finishing train. Wire from 0.3545" to 0.5118" and mild steel for nut wire in sizes less than 0.5905" \times 0.315" have three passes in the intermediate train and five passes in the finishing train. Nut wire in sizes greater than 0.5905" \times 0.315" has three passes in the intermediate train and three passes in the finishing train. Section wire has the same passes as the equivalent round wire.

(4) **Time Study of Wire 0.4724".**—The problems which confronted the investigator were: To determine what happens to the billet in its passage through the mill, and to discover whether all the operations observed are necessary; to separate the interruptions or delays from the working times; to determine the length of individual operations, separating the periods into working and idle times; and to examine the complete sequence of operations, so that in doubtful cases it may be possible to state which operations are necessary, and which can be omitted or improved. Ultimately, the problem was to find the best possible manner of working by the elimination of all irregularities and delays, and to record the time required for each class of wire. By stating the problem in this manner, it was possible to plan the correct method of taking the observations, which was for the observer to follow the individual billet throughout from the withdrawing from the furnace to the last pass, each record of time being sufficiently small to enable a correct analysis to be made.

(5) **Method of Making the Study.**—The stop watch was started when the billet left the furnace, and running times were recorded at the following operations, about twenty billets in each group being observed:—

- (1) Entrance into the first pass of the roughing train.
- (2) Entrance into the eighth pass.
- (3) Emergence from the tenth pass.
- (4) Shearing discard.
- (5) Shearing the first piece of the bar.
- (6) Entrance of the first piece into the eleventh pass.
- (7) Entrance of the first piece into the fourteenth pass.

OPERATION:		PARTICULARS OF PLANT:		ROLLING MILL OBSERVATION FORM NO 10.		TIME.		STOPPAGES.	
ROLLING.		20.7" DIA. ROUGHING MILL, 1-3 HIGH STAND. 15" } DIA. INTERMEDIATE MILL, 1-2 HIGH STAND. 15.5" } 1-3 HIGH STAND.		DEPARTMENT: WIRE MILL. FOREMAN. <i>W</i> DATE: 14.1.1929 START. <i>W</i> FINISH. <i>W</i> OBSERVER. <i>W</i>		NO. FROM TO.			
PRODUCT: ROLLED WIRE.		9.45" DIA. FINISHING MILL, 9-2 HIGH STANDS. 11.5" } 5 STANDS WORKING							
INITIAL SECTION 5 1/2" SQ.		DRIVE: 3000 H.P. STEAM ENGINE.							
FINAL SECTION 0.472 DIA.		WORKERS PER SHIFT.							
WEIGHT: 410 LBS.		FURNACE.							
MATERIAL.		ROUGHING MILL.							
SIEMENS MARTIN STEEL		CONTROLS.							
INITIAL TEMPERATURE.		SHEARS.							
		TOTAL.							
		WORKING HOURS:							
		6 AM. - 8 AM.							
		8-20 AM. - 12 NOON.							
		12-40 PM. - 4 PM.							
		TOOLING							
		L							
		V							
		INITIAL SECTION							
		FINAL SECTION							
		NO. OF							
		MEAN							
		TIME IN MINUTES.							
		1							
		2							
		3							
		4							
		5							
		6							
		7							
		8							
		9							
		10							
		TOTAL							
		AVERAGE TIME.							
		HARD							
		MACHINE							
		TIME.							
		1-10							

FIG. 32a. OBSERVATION FORM.

NO	FROM TO	1	DELAYS.	NO FROM TO	1.	DELAYS	NO FROM TO	1.	DELAYS	NO FROM TO	1.	DELAYS.							
41	-	?	TROUBLE AT INTER-MEDIATE STAND									RUNNING TIME. AVERAGE OF ALL OBSERVATIONS ON THIS CLASS							
42	-	?	-do-																
NO	OPERATION.	TOOLS AND WORKING OR OF ROLLS.	L. X. V/RPM.	INITIAL SECTION.	FINAL SECTION.	NO OF MEN.	TIME IN MINUTES.										TOTAL	AVERAGE	MACH MINES.
							1	2	3	4	5	6	7	8	9	10			
							1	2	3	4	5	6	7	8	9	10			
1	FURNACE TO ROUGHING MILL.	HANDLING WITH TONGS.					R	0.27	1.17	1.18	1.18						0.80	0.20	
2	PASS 1 TO ENTRY IN PASS 8.	4"-1" 20 7/8 DIA. 442/85					R	1.54	1.60	1.56	1.55	1.55	1.58	1.53	1.53	1.53	4.97	0.65	0.75
3	EMERGENCE FROM PASS 10.						R	1.81	1.77	1.74	1.19	1.73	1.55	1.58	1.53	1.53	2.22	0.23	0.98
4	ROUGHING MILL TO SHEARS.	SHEARS AT LIVE ROLLERS.					R	1.23	1.24	1.24	1.23	1.22	1.24	1.23	1.24	1.23	2.32	0.23	0.98
5	SHEARING 1ST PART.						R	1.13	1.12	1.10	1.15	1.12	1.14	1.11	1.11	1.14	1.25	0.12	1.10
6	ENTRY OF 1ST PART PASS 11.	15" DIA. 15" DIA. 20 7/8 DIA. 20 7/8 DIA.					R	1.17	1.13	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.10	0.11	1.21
7	- do - PASS 14.						R	1.32	1.22	1.23	1.24	1.23	1.24	1.23	1.24	1.23	1.10	0.11	1.32
8	- do - PASS 18.						R	1.53	1.40	1.37	1.37	1.36	1.33	1.33	1.33	1.33	1.12	0.11	1.42
9	EMERGENCE OF 1ST PART PASS 18.						R	1.12	1.11	1.10	1.11	1.11	1.11	1.11	1.11	1.11	1.09	0.10	1.58
10	ENTRY OF 2ND PART PASS 18.						R	1.17	1.15	1.18	1.18	1.16	1.18	1.16	1.18	1.16	1.67	0.16	1.74
11	EMERGENCE - do -						R	1.82	1.56	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.47	0.16	1.82
12	ENTRY OF 3RD PART PASS 18.						R	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	0.72	0.08	1.98
13	EMERGENCE - do -						R	1.17	1.15	1.15	1.17	1.15	1.16	1.15	1.16	1.15	1.57	0.15	2.06
							R	1.07	1.07	1.12	1.08	1.13	1.05	1.06	1.06	1.07	0.78	0.07	2.22
							R	1.15	1.14	1.18	1.16	1.16	1.16	1.16	1.16	1.16	1.57	0.15	
							R	2.49	2.20	2.31	2.71	2.18	1.98	2.01	2.06	1.90	1.96	0.15	

X = LENGTH OF ROD IN FEET AFTER EMERGENCE FROM PASS FOR EACH PART OF BILLET (37 1/2).
XX = REVS PER MIN OF THE ENGINE USUALLY 90 THEREFORE V=1400FT. @ 1= INDIVIDUAL TIME: R = RUNNING TIME.

FIG. 32 U. OBSERVATION PLAN.

X = LENGTH OF ROD IN FEET AFTER EMERGENCE FROM PASS FOR EACH PART OF BULLET (137.105).
 XX = REVS PER MIN OF THE ENGINE USUALLY 90 THEREFORE V=1400FT. @ 1= INDIVIDUAL TIME: R = RUNNING TIME.

FIG. 32 V. OBSERVATION PLAN.

- (8) Entrance of the first piece into the eighteenth pass.
- (9) Emergence of the first piece from the eighteenth pass.
- (10) Entrance of the second piece into the eighteenth pass.
- (11) Emergence of the second piece from the eighteenth pass.
- (12) Entrance of the third piece into the eighteenth pass.
- (13) Emergence of the third piece from the eighteenth pass.

The coiling time was taken separately, as the coilers could not be seen from where the observer stood, his view being obstructed by the finishing train.

(6) Analysis of the Observation Forms (front and back) (Figs. 32a and 32b).—The time for each operation was determined from the difference between adjacent running times, and those which showed a marked variation from the average were struck out. The remaining individual figures were then added together in order to obtain a correct average.

(7) Production Diagram.—The average running time for every group of billets was plotted on squared paper, the vertical axis giving the sequence of operations, and the horizontal the time taken at each operation (Fig. 33). The process was subdivided into elements, so that the piece sequence times, and intermediate times, could be considered separately. For instance, in the case of each group of billets being sheared during the intermediate time between the tenth and eleventh passes, this time was subdivided into “roughing train to shears,” “shearing,” and “shears to intermediate train.” The complete production diagram of the first billet was drawn as shown in Fig. 34 from data from Fig. 33 as follows :—

The beginning of the eighteenth pass took place after 1.58 minutes, and the time taken for guiding by hand 0.06 minute, therefore the seventeenth pass must have commenced 1.52 minutes from the start. The seventeenth pass being automatically guided, the sixteenth pass must have taken place 0.02 minute earlier or 1.50 minutes after the start.

The actual piece times are shown as horizontal lines for the various passes.

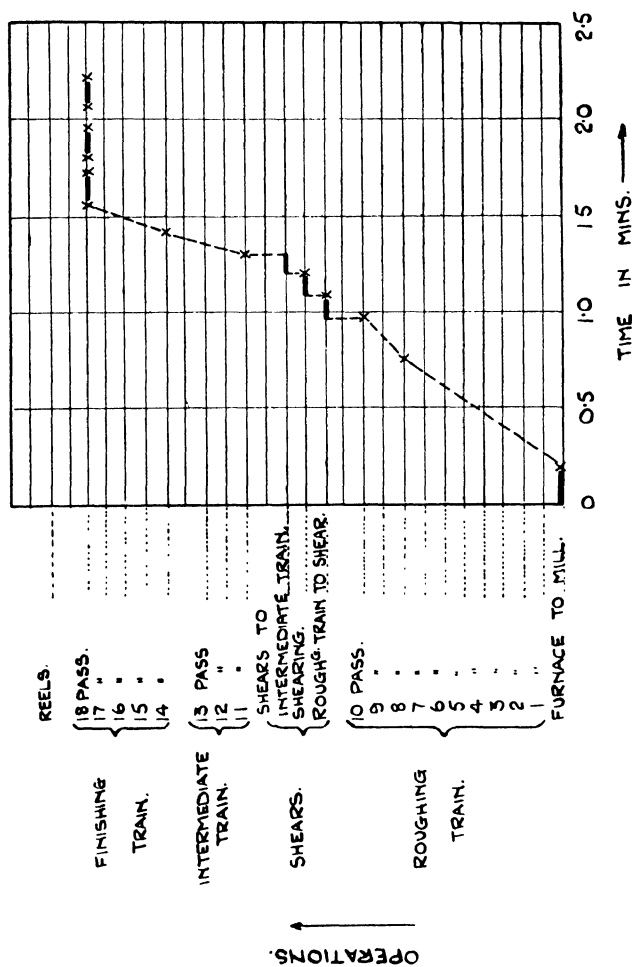


FIG 33. OUTLINE OF RUNNING TIME CLASS 0.4724 DIA.
(TRANSFERRED FROM OBSERVATION FORM.)

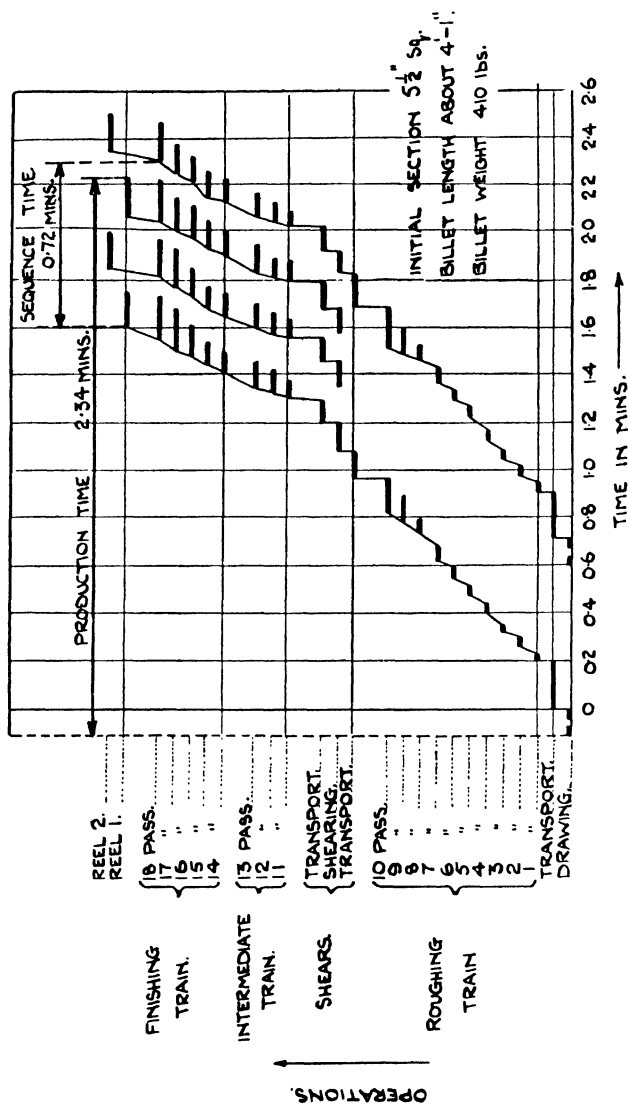


FIG. 34. ROD PRODUCTION DIAGRAM CLASS 0.4724" DIA.

The coiling time for the first part of the billet began at 1.60 and finished at 1.78 minutes.

In the same way, the second and third parts of the billets were plotted, the gap time between the parts being known. The difference between "backward and forward" rolling and loop rolling is interesting, and is clearly seen in the diagrams. In the former case the end of one pass is connected with the beginning of the next, while in the latter case the front ends of each pass are connected.

(8) Piece Time and Piece Sequence Time.—The total time from the beginning of drawing the billet from the furnace to the delivery of the third coil to the transport belt was 2.34 minutes, and is known as the piece time. This time does not give the output of the plant, but can be used for deducing the fall of temperature during rolling, since it gives a measure of the cooling of the material.

The capacity of the mill is controlled by the interval at which the billets follow each other, which is called the piece sequence time.

Rolling being a process of continuous flow, the material running through several passes of different areas and at various speeds, the "capacity cross section" of any part of the plant is fixed by the time that must elapse before the next billet can be handled at any particular place. The mill capacity therefore is dependent upon :—

- (1) The number and construction of the rolls.
- (2) The driving engine.
- (3) The men.
- (4) The auxiliary machines, *i.e.*, shears, cranes, etc.
- (5) The material, *i.e.* temperatures at various passes.

All these controlling factors were investigated, after determining the billet sequence time.

(9) How Sequence Time is Governed by the Mill.—The sequence time for the straight passes can be taken as the longest time necessary for the material to run through the pass, plus the time required for spacing the billets. The sequence time for mechanically looped passes is found by taking the actual rolling time, plus an allowance, such as the time for a gap of, say, 3 feet.

The upper section of Fig. 35 has been developed on these lines, the sequence time being shown as starting from a common vertical axis, which represents the points where the sequence times originate.

The sequence time of the reversing passes can be taken as the piece time of the seventh pass plus the intermediate time, or $0.06 + 0.05 = 0.11$ minute for the looped material; the time of the tenth pass is 0.16 minute plus the minimum intermediate time of 0.01 minute, giving 0.17 minute; the transport to the shear takes 0.12 minute, shearing 0.33 minute per billet and therefore, allocating the time per part of the billet, 0.11 minute per piece; the eleventh to the thirteenth passes in the intermediate train being directly connected with the fourteenth and fifteenth passes of the finishing train, the sequence time is therefore the longest piece time plus the smallest intermediate time; the longest piece time is the thirteenth pass, 0.12 minute; add the smallest intermediate time 0.01 minute—that is 0.13 minute per piece, or 0.39 minute per billet. Passes 16 and 17 are mechanically looped, the sequence time being the seventeenth, which is 0.15 minute + 0.01 minute—that is, 0.16 minute for each piece, or 0.48 minute for each billet. The sequence time of the eighteenth pass is 0.16 minute + 0.01 minute or 0.17 minute—that is, 0.51 minute per billet.

The five belt-driven reels have a minimum intermediate time of 0.11 minute for “taking off” and “starting up,” and the electrically driven reel has a time of 0.17 minute.

The coiling time for the belt-driven reels is equivalent to the piece time of the last pass plus time for “taking off,” and equal to 0.16 minute + 0.11 minute—that is, 0.27 minute, and for the electrically-driven reel 0.16 minute + 0.17 minute, or 0.33 minute.

The average coiling time for each part of the billet is $\frac{(5 \times 0.27) + 0.33}{6} = 0.28$ minute, giving a sequence time of $\frac{0.28}{6}$ or 0.047 minute per section, or 0.141 minute per billet.

As it is not possible to have a consistent running of the last pass, the longest coiling time of 0.33 minute should be taken instead of the average time. Then 0.141 minute is increased to $\frac{0.33 \times 3}{6} = 0.165$ minute. If the sixth reel were not used,

the coiling time would be reduced to $\frac{0.27 \times 3}{5} = 0.162$ minute.

This small difference may not be of practical advantage, but the example does show that every consideration must be examined when determining the factors that govern output.

The piece time of the last pass depends on the length of rod for different diameters, the time of "taking off" being always the same. This constant time for taking off may be compared with adjustment time, which takes place once for each order.

(10) How Sequence Time is Dependent on Men.—The sequence times controlled by the men are shown in the lower part of Fig. 35. The transport of the billets from the furnace to the rolls by the "hurriers out" takes varying times, depending on which door is used. Transport time is 0.18 minute from the nearest door, and the return can be made in the same time. "Clamping into tongs" takes 0.10 minute, therefore the total transport time is $0.18 + 0.18 + 0.10 = 0.46$ minute. The corresponding time from the other door is 0.60 minute. As the "hurriers out" regulate the transport according to the sequence time for each class of wire, the observed time cannot be taken as the shortest possible time. The time shown in Fig. 35 for the "hurriers out" represents the best time which can be maintained when continuously working.

The hand-guided passes of the roughing train are guided by a "rougher" and "lever lad" at each side of the rolls. The two men at the furnace side guide the billet to the third, fifth and seventh passes, and the two men on the reel side the second, fourth, sixth and eighth passes. The rolling time of the billet controlled by the men on the furnace side can be seen in Fig. 36a. The men start work by catching the billet emerging from the second pass, and finish by putting it into the seventh pass, taking 0.35 minute. The men then return to the second pass, taking 0.10 minute, the total time being 0.45 minute. The men at the reel side catch the billet emerging from the first pass and finish work by entering the billet into the eighth pass, 0.54 minute, the return taking 0.10 minute, and at this time the next billet can be put into the first pass. As the billet sequence time is 0.65 minute and the handling and return time of the men 0.54 minute, the difference of 0.11 minute is a stand-

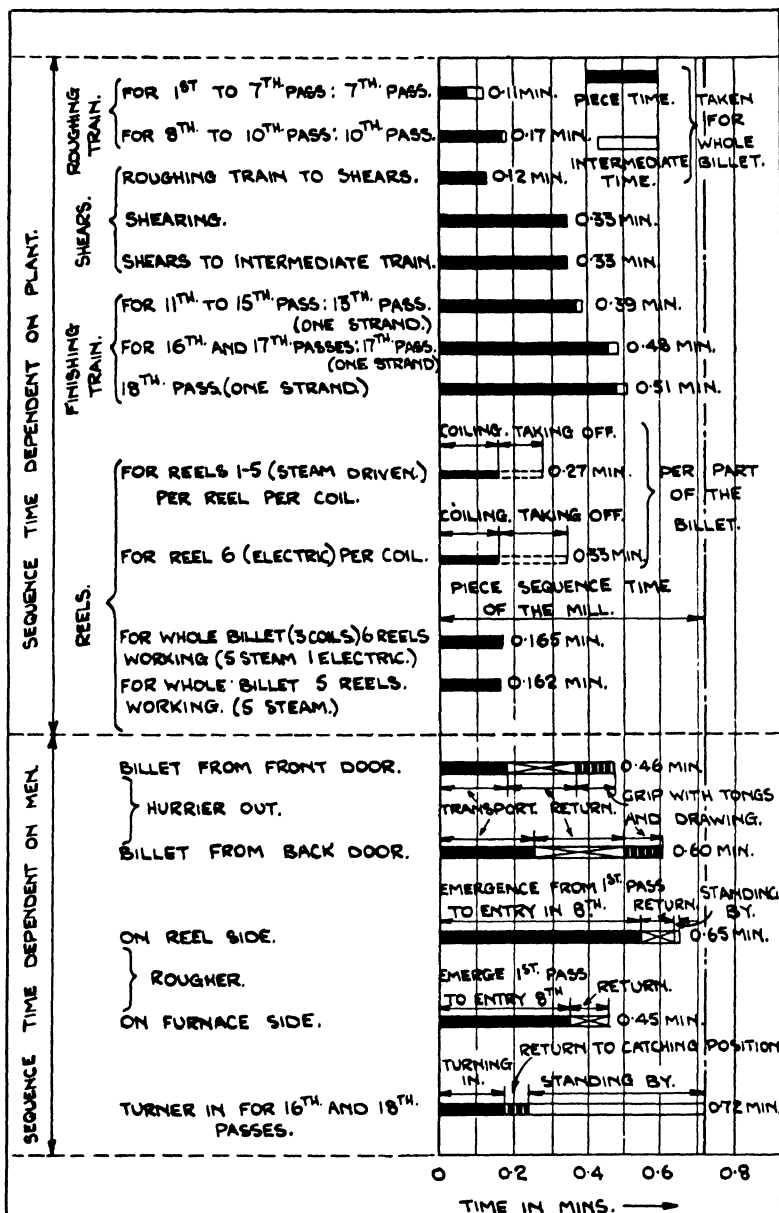


FIG. 35. SEQUENCE TIME DIAGRAM CLASS 0.4724" DIA.

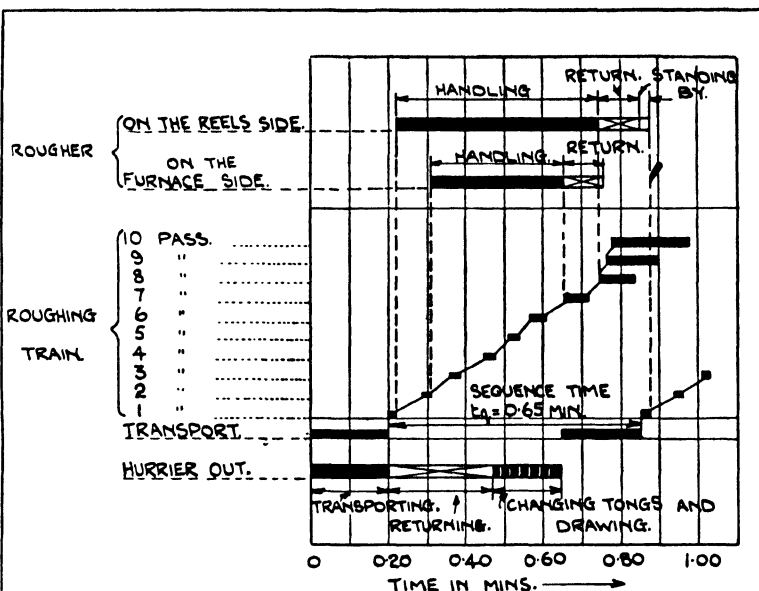


FIG 36A. SEQUENCE TIME FOR ROUGHING TRAIN BEFORE INCREASE OF OUTPUT.

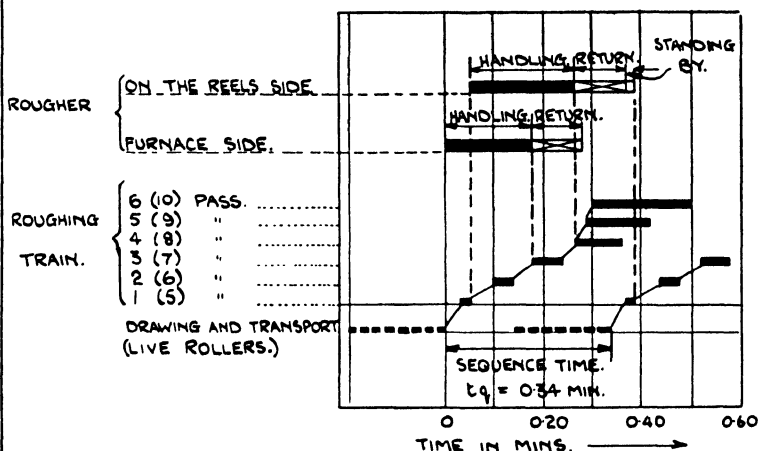


FIG 36B. SEQUENCE TIME FOR ROUGHING TRAIN AFTER INCREASE OF OUTPUT.

by time for the men at this side of the mill. This time could be saved if the lever lad had not to cross the first pass when returning, but could remain on the same side of the billet. This, however, would be dangerous, because of the loop of the ninth pass, when working at the eighth pass. The sequence time for the men is therefore 0.65 minute.

The time of the shear man is equal to the sequence time at this place.

The intermediate train being operated by repeaters, the man at this place is only standing by during rolling, and the man at the controls can do his work easily during the rolling time. The man at the reels has only to move levers, and therefore does not influence the billet sequence time.

The time for turning in is 0.06 minute and returning 0.02 minute for each part of the billet, but this does not give the sequence time. This is found from Figs. 37*a*, 37*b*, 37*c*, where the times of rolling the material are combined with the times of the "turner in." The diagram shows the rolling of the material through sets 2 to 5.

The sequence time for the eighteenth pass was found to be 0.17 minute, and is shown in Fig. 37*a*, the running times being entered on the horizontal axis beginning at *A*, *AB* being the piece time, 0.16 minute, and *BC* the intermediate time, 0.01 minute.

If the second part of the billet enters the pass at *C*, the "turner in" has to catch it when it emerges from the seventeenth pass at *D*, 0.06 minute earlier, which is the actual time of turning in, and has to put it into pass 18 at *C*₁, which is shown directly below point *C*. The "finisher" returns to his starting place after turning in point *E*, and then stands by until he can catch the next part of the billet. The first part entering at *D* has to enter the sixteenth pass at *G*, and is to be caught by the "turner in" when the billet emerges from the fifteenth pass at *H*. The piece time of the eighteenth pass of the first part is finished at *R*. The following piece could enter after an intermediate time of 0.01 minute, but this would be too dangerous for the "turner in." This man has to work close to the material in order to have sufficient leverage to guide it into the rolls, therefore an intermediate time of no less than 0.02 minute is necessary before the next part can be turned in, which is shown as *RR*.

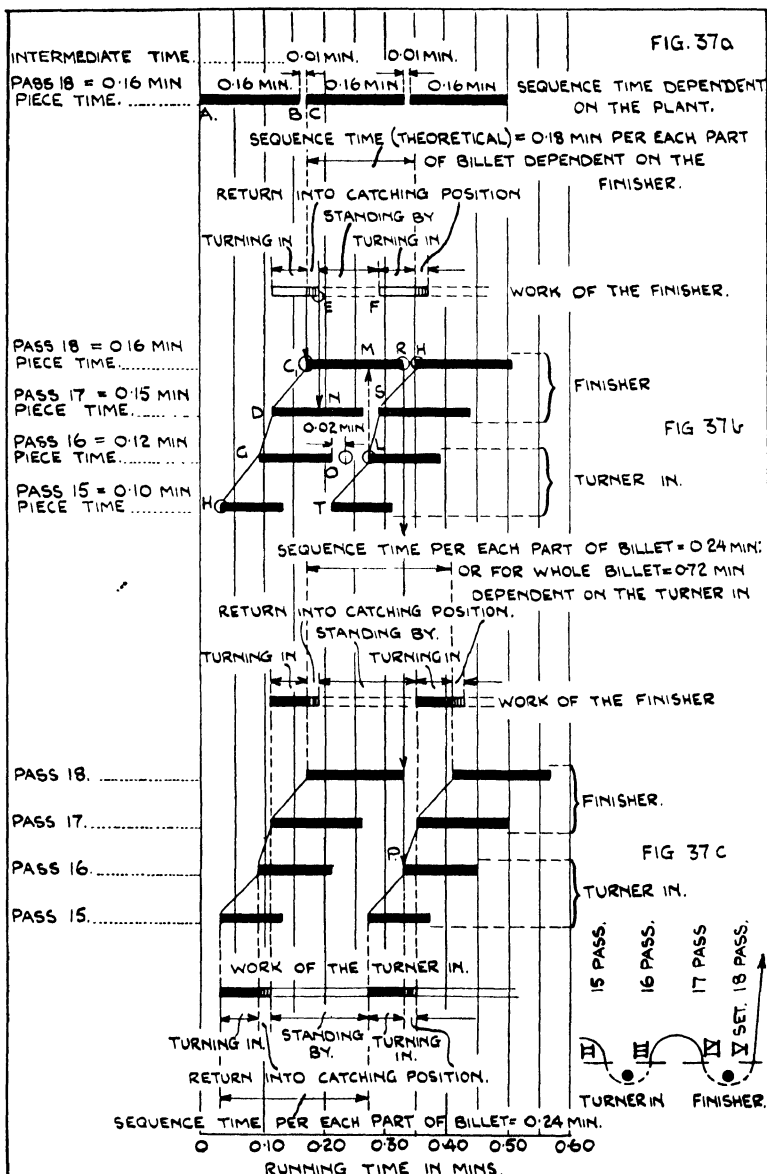


FIG. 37 a, b, and c. CONNECTION BETWEEN SEQUENCE TIME DEPENDENT ON THE PLANT AND SEQUENCE TIME DEPENDENT ON THE TURNER IN.

The "finisher" has to catch the second part at S in order to insert it at K ; the sixteenth pass must begin at L and the fifteenth at T . The standing-by time of the "finisher" is 0.10 minute and is shown at S and equal to EF .

It can be seen in Fig. 37*b* that the "turner in" enters his part of the billet at L , which is when one-third of the preceding part is still in the last pass at M . As it is impossible for the "turner in" to recognise this moment M for inserting into the sixteenth pass, he does it either earlier or later. The earliest time he could insert the billet is at O , which gives an intermediate time of 0.02 minute, which is suitable for the eighteenth pass.

The second part of the billet in the seventeenth pass could emerge at N because the "turner in" is available at this moment to catch the next part of the billet. This is important where multi-pass rolling is carried out with rods of 0.1968" diameter, and where the stand-by time is shortened.

Each part of the billet put into the sixteenth pass earlier than M will be in the seventeenth pass at a time when the entry into the eighteenth pass is barred. The finisher could catch the material, but the loop in the wire would be too large. To avoid this difficulty, the "turners in" are accustomed to remember an entrance or emergence at some other pass and to enter the billet at that moment. In the case in question, the "turner in" observes the emergence of the material from the eighteenth pass; *i.e.* he enters the sixteenth pass at P , Fig. 37*c*, or at a point above where the emergence of the previous material has taken place.

The sequence time for the second part of the billet has been determined in this manner, commencing at point P . The longest sequence time recorded in Fig. 35 determines the sequence of the billet for the whole plant and the output of work, assuming no lost time, and is the time of the eighteenth pass; 0.72 minute per billet.

The output with 400 lb. billets is therefore $400 \times \frac{60}{0.72}$ lb., or 15.3 tons per hour.

(11) Complete Production Time of Several Billets.—The second and following billets can be entered into the production diagram, using the determined billet production time. The

time between one billet and the next or sequence time can be found by basing on the time of the "bottle neck" or longest operation, as can be seen in Fig. 35.

(12) Allowance for Delays.—The delays which were considered were those only which caused a decrease in production. Personal lost time due to meals, collecting wages, etc., are matters which should not occur, because arrangements should be in operation by which the production men can be relieved for these purposes.

Time recorders can be used for observing the progress of work, and thus finding how much time is actually lost by delays, but this method has the defect that the reasons for the delays are not obtained.

Another method sometimes used is by taking the delays from the daily reports and expressing them as a percentage of the basis time, but care is necessary to see that these reports are accurate and reliable. Long delays, such as a quarter of an hour or over, should be excluded from the percentage and a special allowance made.

The most reliable method is by taking time studies for each of the various classes of wire.

Additions for the lost time in the case in question are shown in Table 4, column 8. The differences between the allowances shown are due to the delays being less when fewer passes are used. The delays given in the table were taken from the daily reports because the time for more detailed studies was not available, but they were subsequently checked during several days and found correct.

(13) Comparison of Capacity for Different Groups of Wire under Present Working Conditions.—Columns 1 to 8 in Table 4 contain the results of the investigations for various sizes and qualities of wire and rod, before any alterations were made. High carbon steel was rolled with the same passes as low carbon steel, and it can be seen in column 16 that the engine is the controlling factor for high carbon steel up to 0.2165" diameter, and that the cogging mill is the controlling factor for mild steel. Sizes greater than 0.374" diameter are rolled singly, hence the last pass of the finishing train becomes the bottle neck. Mild steel for nut manufacture, welding wire and boot iron, are controlled either in the roughing train or in the last pass of the

TABLE 4.
Data Completed from the Studies.

Material.	Diameter in Inches or Sec- Inches or Sq.	Charged Billet Section in Inches.	Weight of Billet in lb.	Revolutions of Engine per min.	Piece Sequence Time.			Output in Weight of Charge.	Number of Passes.			Bottle-neck. (16)	Piece Sequence Time.			Output in Weight of Charge.			Bottle-neck (24)						
					Without Lost Time, mins.	With Lost Time, mins.	Addition for Lost Time, %.		Sequence Time per Ton including Lost Time, mins.	Per Hour, tons.	Per Shift of 9 hrs., tons.		Roughing Train. (12)	Intermediate Train. (13)	Finishing Train. (14)	Total No. of Passes. (15)	Without Lost Time, mins.	With Lost Time, mins. (18)		Addition for Lost Time, %.	Sequence Time per Ton including Lost Time, mins. (20)	Per Hour, tons. (21)	Per Shift of 9 hrs., tons. (22)	Increase of Output, %. (23)	
High Carbon Steel	Up to 0-2165	5½ × 5½	410	85	0-735	0-80	9	4-30	13-9	125	10	5	11	26	Engine	0-48	0-53	9	2-85	21	190	51	Becks		
	Up to 0-2165	5½ × 5½	410	100	0-65	0-71	9	3-82	15-7	142	10	5	11	26	Cogging Mill	0-48	0-53	9	2-85	21	190	34			
	0-2205 to 0-256	5½ × 5½	410	100	0-65	0-71	9	3-82	15-7	142	10	5	9	24		0-41	0-45	9	2-40	25	225	59			
	0-260 to 0-2953	5½ × 5½	410	100	0-65	0-71	9	3-82	15-7	142	10	5	9	24		0-41	0-45	9	2-40	25	225	59			
High and Low Carbon Steel	0-2992 to 0-3346	5½ × 5½	410	85	0-65	0-71	9	3-82	15-7	142	10	5	5	20		Finishing Mill, 18th Pass	0-41	0-45	9	2-40	25	225	59	Intermediate Train, 13th Pass	
	0-3386 to 0-374	5½ × 5½	410	85	0-65	0-71	9	3-82	15-7	142	10	5	5	20	0-41		0-45	9	2-40	25	225	59			
	0-378 to 0-4134	5½ × 5½	410	85	0-75	0-79	5	4-25	14-1	127	10	3	5	18	0-41		0-45	9	2-40	25	225	59			
	0-4173 to 0-4527	5½ × 5½	410	85	0-74	0-77	4	4-15	14-4	130	10	3	5	18	0-41		0-43	5	2-30	26-1	235	85			
Mild Steel for Nut Manu- facture	0-4567 to 0-5118	5½ × 5½	410	85	0-72	0-75	4	4-00	15-0	135	10	3	5	18	Cogging Mill	0-41	0-43	4	2-30	26-1	235	80	Increase of Output not recommended on account of Technique of Rolling.		
	Up to 0-140 sq.	5½ × 5½	360	85	0-75	0-77	3	4-72	12-7	115	10	3	5	18		Cogging Mill	0-41	0-43	4	2-30	26-1	235		74	
	0-140 to 0-217 sq.	5½ × 5½	360	85	0-65	0-68	5	4-17	14-4	130	10	3	5	18			Cogging Mill	0-41	0-43	4	2-30	26-1		235	80
	Over 0-217 sq.	5½ × 5½	360	85	0-65	0-68	5	4-17	14-4	130	10	3	5	18				Cogging Mill	0-41	0-43	4	2-30		26-1	235	80
Welding Wire	0-315	5½ × 5½	360	85	0-61	0-66	8	4-05	14-8	133	10	5	5	20	Cogging Mill				0-34	0-37	8	2-27	26-4	238	79	Cogging Mill & 13th Pass In- termediate Train
	0-104 sq.	5½ × 5½	410	85	0-75	0-79	5	4-25	14-1	127	10	3	5	18		Finishing Mill, 18th Pass			Increase of Output not recommended on account of Technique of Rolling.	0-34	0-37	8	2-27	26-4	238		79
Root Iron	0-076 sq.	5½ × 5½	410	90	0-97	1-02	5	5-50	10-9	98	10	3	5	18	Finishing Mill, 18th Pass		Increase of Output not recommended on account of Technique of Rolling.									0-34		0-37	8	2-27	26-4	238	79

Conditions before Rationalisation.

Conditions after Rationalisation, providing the engine
has sufficient power.

finishing train, according to whether the wire is rolled in one or several strands.

B. RATIONALISATION

(1) **Where the Mill is the Controlling Factor.**—In order to increase the output of the mill, the longest billet sequence time must be shortened, and this could only be done providing the rest of the plant could give the greater output; the capacity of the engine, furnaces, etc., must therefore be investigated separately. In most cases the production engineer knows the limits of the capacity of his plant for the various products and where the “bottle neck” is, but is seldom familiar either with figures or the extent to which the various parts of the plant are used with a varied rolling programme. It is important in modern shop management to be able to quote the actual output of each product for each part of the plant.

For instance, it has been stated, for a certain quality and size of wire, that the output is controlled by the engine. This statement in itself is insufficient unless the possible output with a new power unit and the economy of such a change are determined.

To explain what is meant by these remarks, the investigation of wire class 0.4724” diameter is taken.

(2) **Class 0.4724” Diameter (Fig. 35).**—(a) The largest billet sequence time for this group was found to be that of the “turner in” at the finishing train; this was 0.72 minute without lost time and 0.75 minute with a 4 per cent. addition for lost time. The speed of the working of the men was limited by the narrowness of the guides and the effort required to insert the material.

To overcome this difficulty, patent guides which have a large bell mouth and are self-adjusting were proposed. This would enable the man to turn in the strong material earlier, and also to roll several strands at once. In these circumstances the sequence time for the “turner in” could be taken from other investigations with wire of smaller diameter to be 0.18 minute, and this “bottle neck” would be removed. The next “bottle neck” was in the roughing train, where the sequence time was 0.65 minute.

(b) This new limiting time could be shortened only if the

working time of the roller at the reel side of the rolls could be reduced. To achieve this it was proposed to use a billet 4" square instead of $5\frac{1}{2}$ " square, because this would enable the first four passes to be eliminated. In these circumstances the work of the roller can be taken from Fig. 36*b*, which is from turning in the sixth pass to turning in the eighth pass, and occupies 0.21 minute; to this must be added 0.10 minute for returning, and the short pass time of the fifth pass 0.03 minute, and so the sequence time at the roughing train becomes 0.34 minute.

(c) The limiting time is now the transport time of the "hurriers out", which is 0.60 minute or 0.46 minute, according to the door of the furnace from which the billet comes. This time could be shortened by fitting live rollers from the furnace to the roughing train, and, since several billets could be on the live rollers at once, the sequence time would be the time for drawing the billet from the furnace; this time was shorter than the time for the man on the reel side of the rolls, and ceased therefore to be a limiting time. The next largest sequence time was the thirteenth pass in the intermediate train, which was 0.43 minute, allowing 4 per cent. for lost time.

This could not be reduced without making extensive changes in the lay-out of the mill, which could not be recommended, and the rationalisation is completed as far as it can profitably be taken. Thus, the increase of output is $\frac{(0.74 - 0.43) \times 100}{0.43}$, or 74 per cent.; and it was obtained by

(a) Patent guides.

(b) A smaller billet section ($4" \times 4"$).

(c) Live rollers to convey the billets from the furnace to the mill.

The billet production diagram for the shortened billet sequence time is given in Fig. 38.

(3) Comparison of Capacity for all Classes.—In the same manner the shortest sequence times for all classes of wire were determined, ignoring for the moment any limitation that might be imposed by the drive; and these results are given in Table 4, columns 17 to 24, column 23 showing the increase in output.

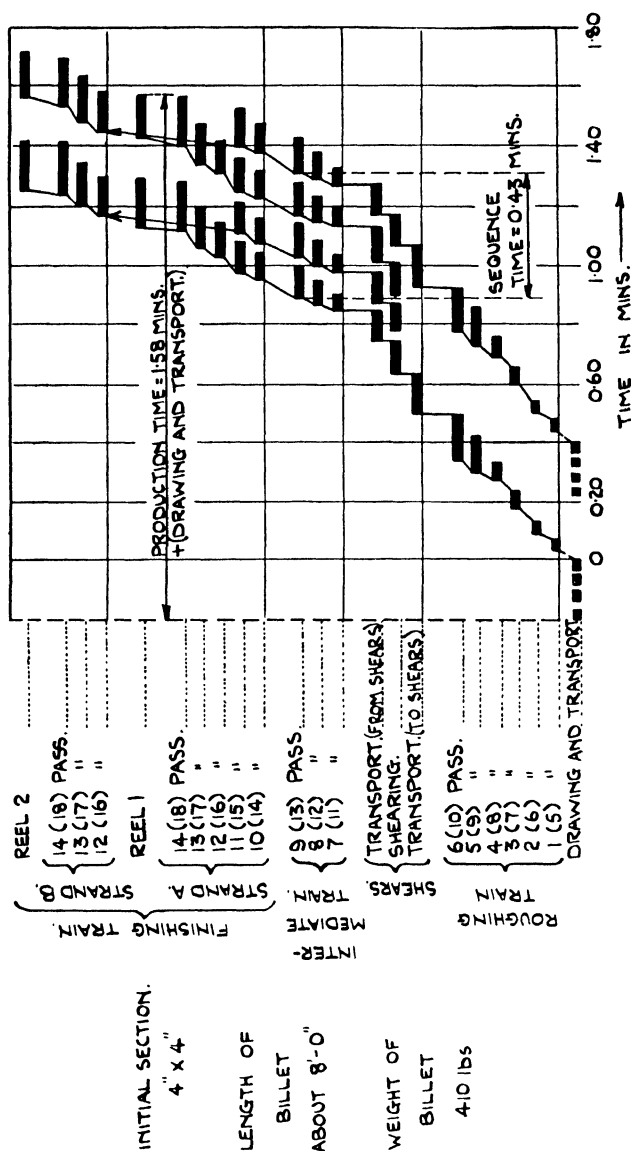


FIG 38. ROD PRODUCTION DIAGRAM. CLASS 0.4724" DIAM. AFTER INCREASE OF OUTPUT.

The limiting factor for classes 0.1968" to 0.2165" diameter is the coiling, and the thirteenth pass in the intermediate train is the limit for wire over 0.2165" diameter. Increases of output in boot-iron and nut-wire could not be obtained because of technical difficulties. Welding wire being rolled from a smaller billet in two parts, the "bottle neck" occurred in the thirteenth pass of the intermediate train and the roughing train, and the sequence time was 0.34 minute.

(4) The Engine as Limiting Factor.—Up to this point the mill only had been considered, but it was now necessary to examine the power output of the engine to determine whether the increase of output calculated upon could be obtained from the power point of view, and if not, what was the limit. First, a comparison was made between the economy that would result if the mill were run with the increases of output determined above, and the capital costs if it were necessary to instal a more powerful drive. As the latter was found to be considerable, the possibilities of the existing drive were examined further.

The work done by the engine during the rolling of the various classes of wire was found by using an integrating indicator, and a record was obtained for the period of investigation, of the number of billets rolled, and the areas of indicator diagrams, which, with conditions as to diameters of cylinders and steam pressure, gave a means of determining the power consumed in Kw.h. per ton.

The measured consumption in Kw.h. per ton was found to vary considerably for the same class of wire, and this variation was more pronounced the smaller the ton sequence time. The power consumed was therefore referred to a common sequence time (stipulated sequence time), in order that a comparison might be made.

Taking the total consumption of power as the sum of the power necessary for driving the engine and mill when running light (that is the friction load), and the additional power used for rolling the material (that is the rolling load), two equations have been developed which give all the information necessary to show the relation between load and ton sequence time.

These equations are stated below, but their derivation is not given, to avoid diverting the reader's thoughts from more important points.

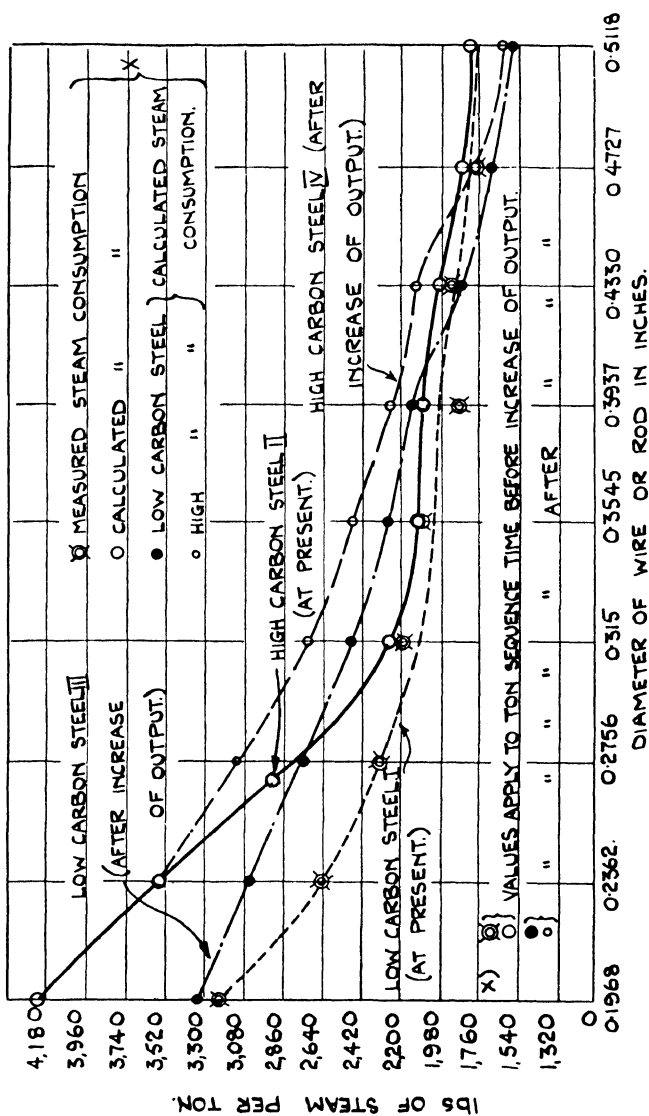


FIG.39 CONSUMPTION OF STEAM IN lbs PER TON OF PRODUCTION.

If P_u = Maximum useful power possible in Kw.

p_o = power consumed in light running in Kw.h. per minute.

p_u = External load in Kw.h. per ton of rolled product.

p = Total power in Kw.h. per ton.

t , min. = shortest possible ton sequence time in minutes.

then

$$p_u = p - p_o \times t_s$$

and

$$t_s \text{ min.} = \frac{60 \times p_u}{P_u}$$

or stated in words, "the useful power absorbed at the time of the study in Kw.h. per ton of rolled product is equal to the total power consumption in Kw.h. per ton at the same time, less the 'no load' power consumption in Kw.h. during one minute multiplied by the ton sequence time at the same time." And "the shortest possible ton sequence time in minutes is equal to the useful power consumption in Kw.h. per ton multiplied by 60, and divided by the maximum useful power that can be developed by the engine in Kw."

The shortest possible ton sequence time can now be calculated by the second equation, because the maximum useful power output is constant for the engine and mill in question, and the useful power in Kw.h. per ton during the test is known from the first equation in which the total power consumed in Kw.h. per ton and the ton sequence time in minutes are found by observation; the "no load" power in Kw.h. per minute is constant for the plant.

The actual figures for this case are :—

p_o = 7.17 Kw.h. per minute if 9 sets of the finishing train are working.

and = 6.3 Kw.h. per minute if 5 sets are working.

P_u = 2200 — 430 Kw. for 9 sets working.

= 2200 — 378 Kw. ,, 5 ,, ,,

Two thousand two hundred Kw. is the maximum possible total load for the engine and 430 Kw. and 378 Kw. the light (friction) loads for 9 stands and 5 stands respectively, working in the finishing train.

(5) **Summary of the Increase in Output for all Classes of Wire, at the Limiting Load of the Engine.**—The shortest possible ton

sequence time for all classes of high and low carbon wire are shown in Table 5, column 3. The ton sequence times obtained from time studies are shown in column 2, and the ton sequence time which could be obtained from the plant with unlimited power for the drive in column 4. The basis times given in columns 2 to 4 refer to work without delays. The longest sequence times in columns 3 and 4 are the times obtainable with the original condition of the drive, and are shown in italics. It can be seen that the controlling factor is the engine for low carbon wire up to 0.3545" diameter and high carbon wire up to 0.3937" diameter, the remaining sizes being controlled by the mill. The italicised basis times given in columns 3 and 4 are given in column 6 with lost time additions, and column 5 shows the original ton sequence times with lost time additions. The possible increase in output is shown in column 7 as a percentage.

TABLE 5.

Possible Increase of Production if the Driving Engine is Used to Full Capacity.

	Type and Size of Wire.	Ton Sequence Time in Mins.					Increase of Produc- tion. %.
		Without Lost Time Caused by			With Lost Time.		
		Present.	Engine.	Mill.	Present.	After Increase.	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Low Carbon Steel.	0.1968	3.50	<i>3.4</i>	2.58	3.82	3.70	3
	0.2362	3.50	<i>3.05</i>	2.20	3.82	3.30	16
	0.2756	3.50	<i>2.78</i>	2.20	3.82	3.00	27
	0.3150	3.50	<i>2.47</i>	2.20	3.82	2.70	41
	0.3545	3.50	<i>2.27</i>	2.20	3.82	2.50	53
	0.3937	4.03	2.10	<i>2.20</i>	4.25	2.30	85
	0.4330	3.98	1.97	<i>2.20</i>	4.15	2.30	80
	0.4727	3.87	1.87	<i>2.20</i>	4.00	2.30	74
	0.5118	3.87	1.80	<i>2.20</i>	4.00	2.30	74
High Carbon Steel.	0.1968	4.25	<i>4.25</i>	2.58	4.60	4.60	0
	0.2362	3.60	<i>3.60</i>	2.20	3.90	3.90	0
	0.2756	3.50	<i>3.15</i>	2.20	3.82	3.40	12
	0.3150	3.50	<i>2.63</i>	2.20	3.82	2.90	32
	0.3545	3.50	<i>2.47</i>	2.20	3.82	2.70	41
	0.3937	4.03	<i>2.27</i>	2.20	4.25	2.40	77
	0.4330	3.98	2.10	<i>2.20</i>	4.15	2.30	80
	0.4727	3.87	1.94	<i>2.20</i>	4.00	2.30	74
	0.5118	3.87	1.84	<i>2.20</i>	4.00	2.30	74

Heavy figures show bottle necks.

(6) **Consumption of Steam.**—No special study was instituted for this determination, because the necessary data could be obtained accurately from routine figures.

The steam consumption figures are shown in Fig. 39. Curves I and II show the results for the original conditions of the mill for both low and high carbon steels.

Curves III and IV show the effect after alterations to the plant, the consumption of steam in the latter case being higher where previously the engine was the controlling factor, but lower for low carbon wire from 0.4330" to 0.5118" diameter and high carbon wire from 0.4724" to 0.5118" diameter. The drop of efficiency in the engine is reflected by a break in the curves for low carbon wire at 0.3937" diameter, and for high carbon at 0.433" diameter, the engine ceasing to be the controlling factor for large diameters.

The diagram of the steam consumption appeared to indicate that it would not be economical to increase the output of the mill, as the power costs increase likewise. However, the production costs depend to a large extent on the time which is necessary for rolling each ton, therefore it was possible that the total costs might become lower with a decreasing ton sequence time, in spite of increasing power costs.

(7) **Power Consumed in Rolling.**—The power consumed in rolling for different classes of wire found by calculation, according to the previous equation, is shown in Fig. 40 plotted against the diameter of rods. It will be seen that the consumption of power is not proportional to the diameter of wire, the power increasing more rapidly for the finer sizes, apparently due to the greater heat loss in the guides, this being more pronounced in the harder qualities.

(8) **Stipulated Consumption of Power.**—The stipulated consumption of power can be stated to be the power which is required for rolling each class of wire in the minimum ton sequence time, and Fig. 41 shows the relation between the consumption of power, the sequence time and the limiting load of the engine. The points shown on the graph are taken from the experiments. They are between the diagonal given by the maximum power of the engine, 2200 Kw. , or $\frac{2200}{60} = 36.6 \text{ Kw./1 min.}$, 73.2 Kw./2 min. , 110 Kw./3 min. , etc., and the

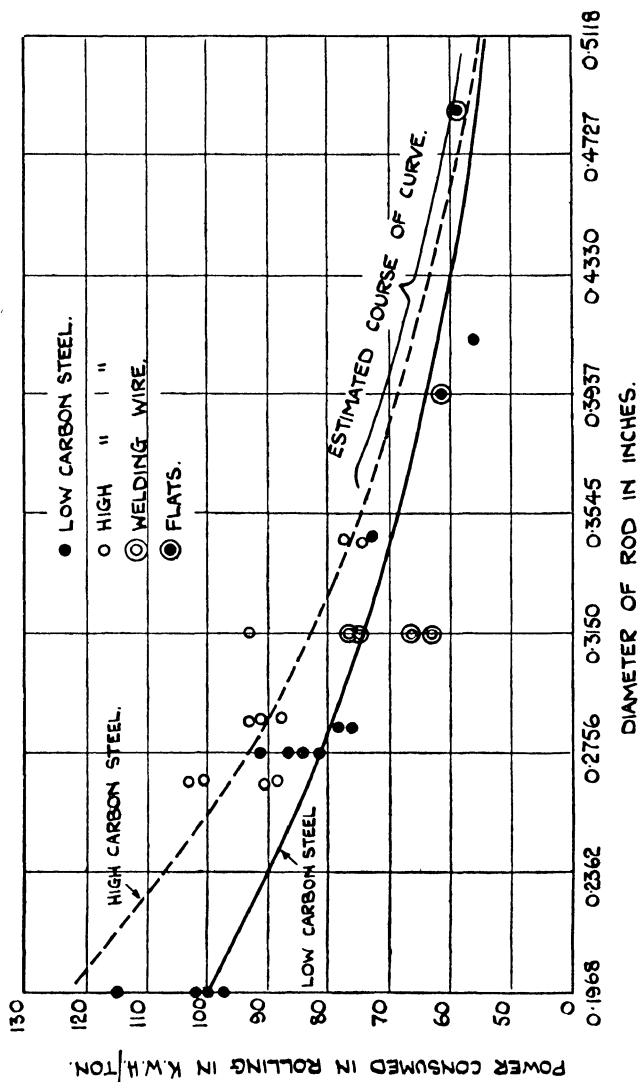


FIG 40. RELATION BETWEEN POWER CONSUMPTION IN ROLLING AND DIAMETER OF RODS.

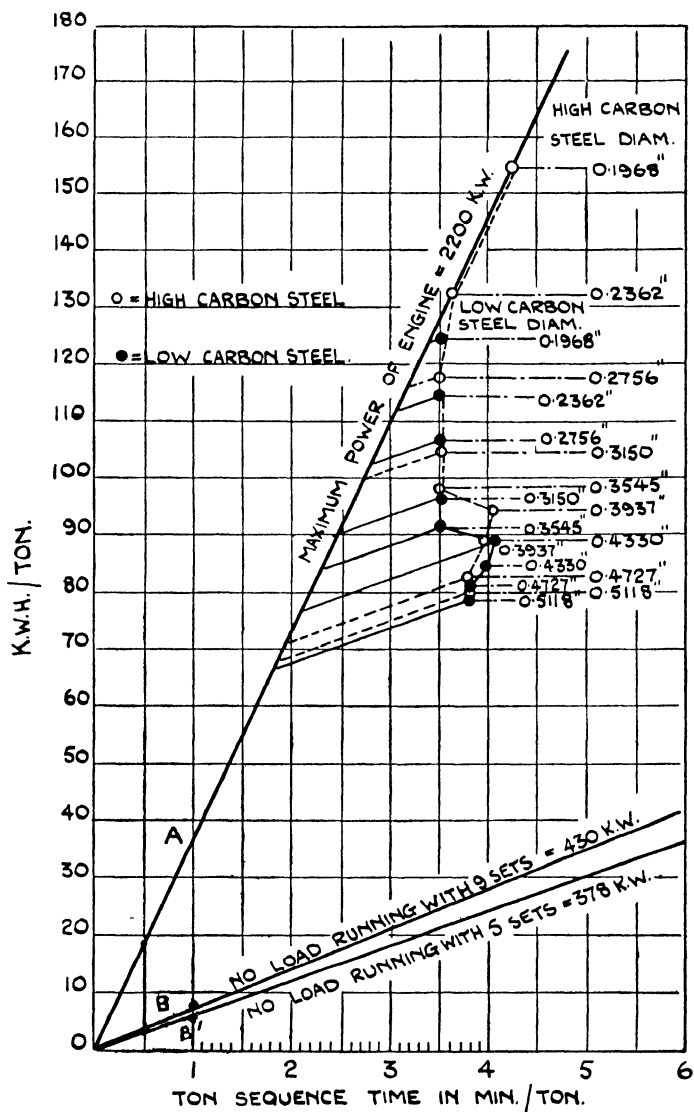


FIG.41.· DIAGRAM OF STIPULATED CONSUMPTION OF POWER.

no-load lines of the engine 430 Kw. for 9 sets, and 378 Kw. for 5 sets. If it were possible to shorten the ton sequence time, these points would travel along lines parallel to the no-load lines of the engine to the crossing point with the maximum power line, which indicates the shortest possible sequence time. As may be seen, the maximum output of the engine is nearly reached for low carbon wire of 0.1968" diameter, and the engine load decreases with increasing wire diameters having the same ton sequence time. A surplus of power is available for wire diameters over 0.3937" diameter, due to the longer ton sequence time. High carbon wire 0.1968" diameter and 0.2362" diameter coincide with the line of maximum output of the engine; in other words, the ton sequence time is dependent on the engine. If the diameter of the wire increases, the point indicating the power consumption depending on the ton sequence time travels first along the line of the limiting load, to the vertical line, which is determined by the shortest ton sequence time of the mill under the original conditions. The consumption of power decreases at the same ton sequence time as the point travels vertically down to a deflection in the curve, to the right at 0.3937" diameter, caused by a longer ton sequence time, depending on the mill. The influence of the sequence time is perceivable from the greater part of the whole power consumption taken by no-load running. Thus Fig. 41 enables the shortest possible ton sequence time of the limiting load to be obtained graphically. The greatest output of work per minute which can be delivered by the engine is equal to the line $A-1$ in the diagram, and the greatest possible power consumption in rolling per minute is given by AB or AB' , according to the power consumed for no-load.

(9) **Nomogram of the Ton Sequence Time.**—The nomogram shown in Fig. 42 gives the possible ton sequence time in relation to the power consumed in rolling in Kw.h. per ton and the loading of the engine; and enables the equation $t, \text{ min.} = \frac{60 \times p_u}{P_u}$ to be solved graphically.

The nomogram is based on logarithmic division, *i.e.* \log (minimum ton sequence time) = \log (power consumed in rolling Kw.h. per ton) — $\log 29.5$ or \log (minimum ton sequence time) = \log (power consumed in rolling in Kw.h. per ton) — $\log 30.4$.

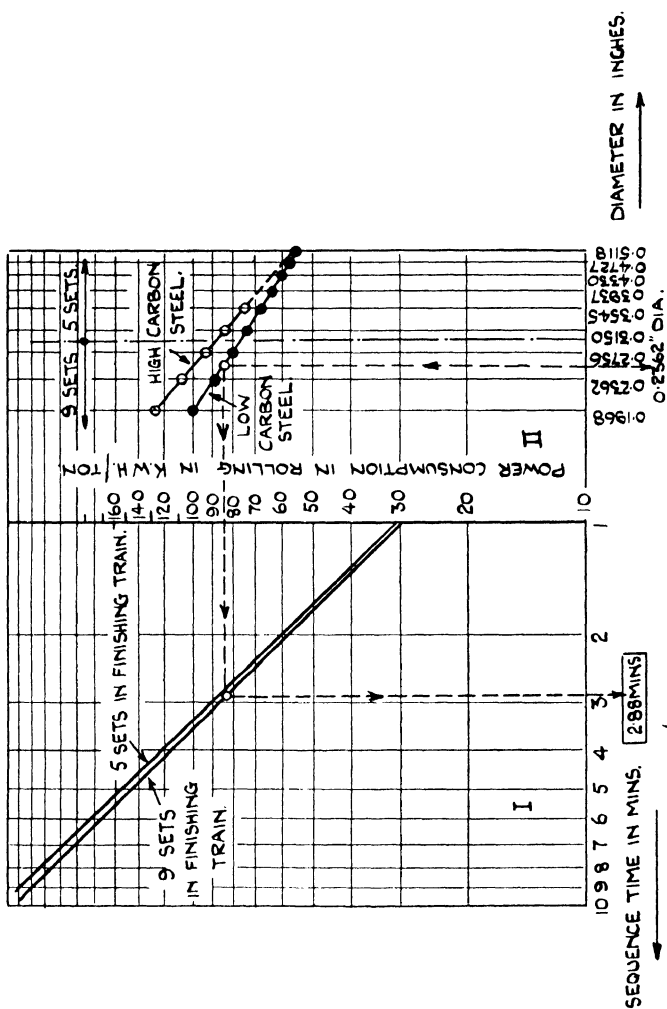


FIG.42 NOMOGRAM FOR DETERMINATION OF THE POSSIBLE TON SEQUENCE TIME FROM THE POWER CONSUMPTION IN ROLLING AND THE LOAD ON THE ENGINE.

The power consumed in rolling in Kw.h. per ton is shown plotted on the vertical axis and the ton sequence time of the horizontal axis, in logarithmic scale; the two divisions 29.5 and 30.4 are shown by two straight lines inclined at 45°. The starting points of these lines were based on the following:—

For minimum Ton Sequence Time = 1

$$\begin{aligned}\log (\text{power consumed in rolling in Kw.h. per ton}) &= \log 29.5 \\ &\text{or} = \log 30.4\end{aligned}$$

The second quadrant was used for plotting the diameter of wire on the horizontal axis in logarithmic division, and the figures for consumption of power in rolling were taken from Fig. 41. The curves for high and low carbon wire are nearly straight lines, and give the relation between power consumed in rolling and diameter of wire. The shortest possible sequence time of any diameter between 0.1968" and 0.5118" can be found from this chart. For instance, low carbon wire of 0.260" diameter, which is rolled in 9 sets in the finishing mill, has a consumption of power of about 85 Kw. per ton and a sequence time of 2.88 minutes per ton.

(10) The Furnace as Limiting Factor.—Finally, it was necessary to find out if the furnace would allow the new calculated outputs to be obtained from the mill. A cross-section of the furnace is shown in Fig. 43, there being two chambers with a hearth area of 580 sq. ft., and the output necessary from the furnace, before and after the proposed changes, is shown in Table 6. The maximum output required from the furnace was 99 and 100.5 lb. per sq. ft., and appeared to be very high.

The capacity of the furnace was found to be 110 billets per chamber when using 5½" square billets. The start and finish of one load of similar billets were observed, and the results were plotted as shown in Fig. 43.

The horizontal line shows the time during which no material was drawn, and the slope of the other part of the line gives a measure of the speed of the material passing through the furnace. The highest speed was obtained during one afternoon between 1.16 p.m. and 3.13 p.m. with a total of 114 billets, *i.e.* more than the capacity of one chamber without any difference in temperature between the first and last billets. This represented an output of 82 lb. per sq. ft. per hour.

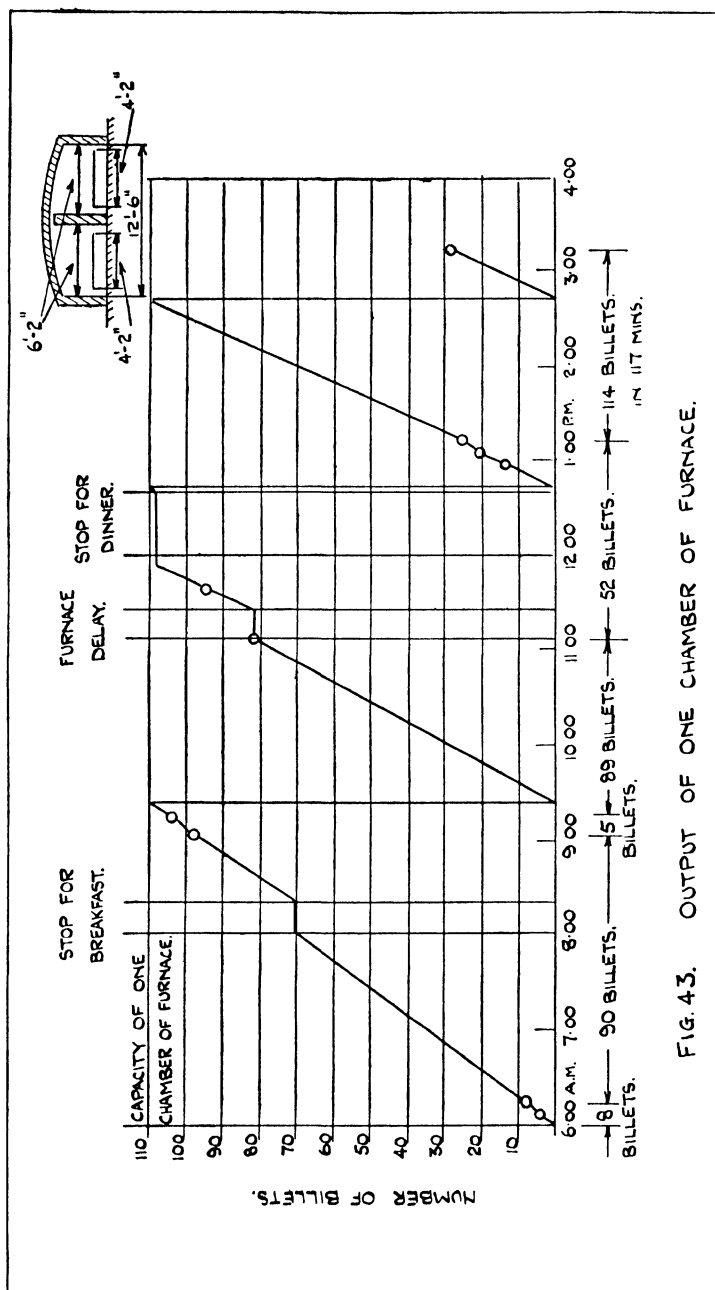


FIG. 43. OUTPUT OF ONE CHAMBER OF FURNACE.

It was agreed that the smaller billet section would give a slightly better result; also that the desired output of 100 lb. per sq. ft. per hour could be obtained either by increasing the number of burners or enlarging the furnace.

TABLE 6.

Output of Furnace Before and After Increase of Mill Output.

[Hearth Area 49 ft. 0 in. \times 11 ft. 9½ in. = 580 sq. ft.]

Present Practice.				After Increase of the Mill Output.			
				Without Strengthening the Drive.		With Strengthening the Drive.	
Class, ins. dia.	Tons/hr.	Lb./in.		Tons/hr.	Lb./in.	Tons/hr.	Lb./in.
Low Carbon Steel.	0-1968	15·7	60	16·2	61·5	21	80
	0-2362	15·7	60	18·2	69·2	25	95
	0-2756	15·7	60	20·0	76·0	25	95
	0-315	15·7	60	22·2	84·5	25	95
	0-3545	15·7	60	24·0	91·0	25	95
	0-3937	14·1	53·5	26·1	99·5	26·1	99·5
	0-4330	14·4	54·5	26·1	99·5	26·1	99·5
	0-4727	15·0	59·5	26·1	99·5	26·1	99·5
	0-5118	15·0	59·5	26·1	99·5	26·1	99·5
High Carbon Steel.	0-1968	13·0	49·5	13	49·5	21	80
	0-2362	15·4	58·5	15·4	58·5	25	95
	0-2756	15·7	60	17·6	67·0	25	95
	0-315	15·7	60	20·7	79·0	25	95
	0-3545	15·7	60	22·2	84·5	25	95
	0-3937	14·1	53·5	25·0	95·0	26·1	99·5
	0-4330	14·4	54·5	26·1	99·5	26·1	99·5
	0-4727	15·0	59·5	26·1	99·5	26·1	99·5
	0-5118	15·0	59·5	26·1	99·5	26·1	99·5
Mild Steel for Nut Manufacture.	I	12·7	48·3	No increase of output.			
	II	14·4	54·5				
	III	14·4	54·5				
Boot Iron.	1	14·1	53·5				
	2	10·9	41·5				
Welding Wire.	0-315	14·8	56·2	22·2	84·5	26·4	100·5

C. THE WAGES PROBLEM.

(1) **Piece-Work Wages.**—The preceding investigation shows what was required to obtain the maximum output from the

plant, but this could only be achieved if the men would work in the best possible manner and in the shortest time, therefore it was considered necessary to offer them some form of inducement to do this.

(2) **Manning Plan.**—To be able to determine the piece-work wages, it was necessary to know the time required to produce each unit ton for each class of wire, and the number of men required during this time.

The individual work of the men was then studied, including the bundling and despatching of coils and pointing of rods (see Fig. 44).

The manning plan is shown in Table 7.—The workmen divided into two groups, (a) day shift, (b) night shift, and further divided into two sub-groups, sub-group (1) being under the engineers, and sub-group (2) the essential mill workers.

The producing men of each group were taken as the basis for each calculation of the piece-work rates. The night-shift men did not produce, their work consisting of setting guides and roll changing.

The number of men taken into account in determining the piece-work time can be found from the total number of men by subtracting 7 night-shift men, 5 general workers and 2 crane drivers.

Two different cases were then considered :—

First, with new roller gears and pushers at the furnace, and a smaller billet section ;

Secondly, with a completely mechanised mill, which would enable one man to work at the cogging rolls, thus reducing the manning by 3 rollers and 3 lever lads, and lifting tables which would reduce the number by a further 6 men.

(3) **Piece-Work Basis.**—The basis of the piece-work system arranged was (a) standard times—that is, the time necessary for an average man in an average performance to produce a ton of material—was determined by measurement and calculation. (b) The rates for the different grades of workers were stated in pence per minute, and each worker was paid the rate appropriate to his grade.

So, if t_q is the ton sequence time in minutes, and u is the rate of any man, $t_q \times u$ is his piece-work rate per ton produced.

In the case of a mill, the ton sequence time used for this

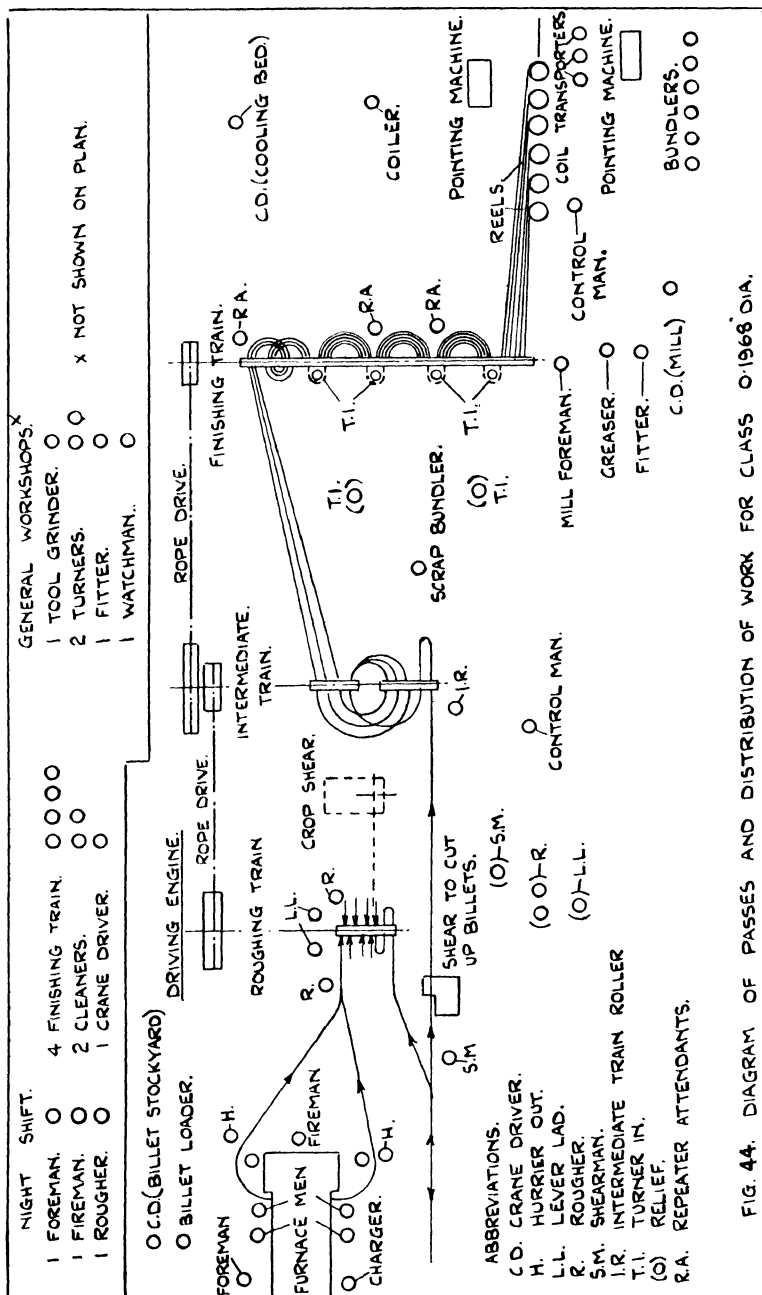


TABLE 7.
Manning Plan.

Occupation.	Before the Time Study. (2)	After the Increase in Output.		Piece Work Basis. d./min. [Conversion Factor]†	Remarks. (6)
		Mill not Mechanised. (3)	Mill Mechanised. (4)		
(1)				(5)	
A. DAYSHIFT.					
I. Belonging to the machine shop :					
Reel driver	1	1	1	0.16	
Greaser	1	1	1	0.15	
Fitter	(1)*	3	3	0.15 (0.15)	2 crane drivers (day rate). 1 crane driver (piece work).
Crane driver	3				
II. Belonging to the mill :					
1. Machine shop :					
Roll grinder	1	1	1	—	Special rate.
Roll turner	2	2	2	—	"
Roll fitter	1	1	1	0.16	Av. piece-work rate.
Shop attendant	1			—	Day rate (old age).
2. Billet stockyard and furnace—					
Foreman billet stock	1	1	1	0.16	
Billet loader	(1)*			—	
Charger	1	1	1	0.16	
Yardman	2	2	2	0.25	
First furnace man	2	2	2	0.21	
Second furnace man	2	2	2	0.20	
First burner	2	2	2	0.17	
Assistant hurrier out	2	2	2	0.20	
Furnace attendant	1	1	1	—	
3. Roughing mill—					
First rougher	1	1	1	0.24	
Second rougher	3	3	3	0.22	
Lever lad	3	3	—	0.18	
4. Live rollers, shears, roughing mill—					
Reel driver	1	1	1	0.16	
Shearman	2	2	2	0.16	
Boller intermediate train	1	1	1	0.23	
Total number of men not dependent on the class of wire rolled	32 (34)	28	22	—	25 originally on piece work. After increase in output 21 and 16 respectively.

5. Finishing train cooling Bank—														
Wire dia., ins.														
A. 0-1963	B. 0-2362	C. 0-2753	D. 0-315 to 0-5118	E. Nut Steel	A.	B.	C.	D.	E.	A.	B.	C.	D.	E.
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	4	4	2	2	4	4	4	2	2	4	4	4	2	2
2	2	2	1	1	2	2	2	1	1	2	2	2	1	1
* (2) + 1	* (1) + 1				1	1	1	1	1	1	1	1	1	1
—	—	—	—	—	1	1	1	—	—	1	1	1	—	—
1	1	1	—	—	1	1	1	—	—	1	1	1	—	—
1	1	1	—	—	1	1	1	—	—	1	1	1	—	—
3	3	3	—	—	4	4	4	5	5	4	4	4	5	5
3	3	3	—	—	4	4	4	5	5	4	4	4	5	5
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Total number of men dependent on class of wire					19	19	20	22	23	19	19	20	22	23
Number of men controlling piece work rate					(21) 19	(20) 19	21	(21) 21	(25) 22	40	40	41	43	38
					44	44	46	46	47	34	34	35	37	38
					All men on piece work.					Av. : 2d. for 0-1963* dia.				
					All men on day shift less 7 men [= 5 men in mill and 2 crane drivers paid on piece work (average)].					—				

calculation was the ton sequence time of the mill, and it does not matter, as far as the wages account is concerned, whether an individual worker is fully occupied or has to stand by part of the time. It is the concern of the management to see that the work is so arranged and production so balanced that each man is as fully occupied as possible; and each man is entitled to be paid for the full number of minutes in his shift according to his rate per minute.

The piece-work costs or rates per ton for the mill can be calculated from the standard ton sequence time and the number of men required for each class of wire rod.

For example, the standard time t_q for low carbon steel rod 0.1968" diameter is 4 minutes per ton. The number of men necessary is 44. The allowed time per ton is therefore $4 \times 44 = 176$ minutes.

In a particular shift, 145 tons were produced in 386 actual man-hours worked; two men out of the 44 had each had 5 hours leave, and each of the others had worked 9 hours, so

$$44 \times 9 - (2 \times 5) = 386 \text{ hours.}$$

The allowed or stipulated time for 145 tons would be 145×176 man-minutes, and the actual time occupied was 386 hours, so that the work was done at the rate of $\frac{145 \times 176}{386} = 66$ piece-work minutes per hour, and this measures the rate at which each worker would be paid for each hour of this particular shift. Thus a man rated at 10*d.* per hour would receive $10 \times \frac{66}{60} = 11*d.*$ per hour for this shift.

This performance was obtained: (a) by exceeding the stipulated rate of production for the mill and (b) by the rest of the squad doing the work of the two men who were absent a total of 10 man-hours.

The wage cost per ton for cost accounting purposes is found by taking the total rate per minute of the squad and multiplying it by the stipulated number of minutes per ton (in this case 4). This payment for piece-work on a time basis had a certain psychological value. Money was not spoken of in discussing wages, time was substituted. Workmen dissatisfied did not complain that piece-work rates were too low, they said that the

standard times were insufficient to give reasonable earnings; the truth or otherwise of this statement could be immediately demonstrated with a stop-watch. This shows the value of choosing time as a measure of work. If the stipulated or standard times are carefully, accurately, and fairly determined, the workers can be furnished at once with an irrefutable demonstration of their sufficiency; if an error against the men has been made, it can be discovered and rectified without loss of dignity. Once fixed and agreed in this way, the times remain until the process has been changed.

The method may be summarised as follows: Rates per minute or per hour for piece work are agreed upon for each class of worker; the average piece work (the old system if any) earning over a period may, if desired, be taken as a basis. The rates decided upon for this mill are found in Table 7, column 5, and were found by dividing the average hourly earnings by 60.

Standard or piece-work times and number of men required were determined for each class of wire by time studies, and are shown in Table 8, these figures subsequently being posted up in the shops.

As the performance figures were based on finished tonnage, a yield factor of 94 per cent. was taken for converting charged weight into finished tonnage.

(4) Daily Report of Performance.—In the operation of such a mill as this there are unavoidable delays from time to time, and it is not possible, therefore, to assume that all shift hours are piece-work hours. In order to ensure that piece-work hours were correctly and accurately recorded, and that complete information regarding stoppages and their causes was obtained, daily performance reports were made and charted. These reports formed the basis of piece-work payments, and sometimes for the reductions of delays and cost information.

An example of these daily performance reports is shown in Fig. 45. The normal number of men during the day shift was 49 (*i.e.* rolling-mill men only) giving 441 working hours for a nine-hour shift. In addition to these men, there were one crane driver, one drum driver, one fitter, and two crane drivers who worked four hours each, giving a total time of 35 hours.

From the normal quota of men, one man was lent to another department and two men were away ill.

TABLE 8.
Piece-Work Time.

Class, ins. (1)	Sequence Time in mins, <i>t</i> . (2)	Unity Number of Men Occupied. (3)	Piece Time in mins. (4)	Remarks. (5)
Low Carbon Steel.	0.1968 to 0.2165	44	176	During the night shift the two crane-drivers of the main shop and despatch shop and the roll fitter are paid an average piece-work rate, according to their conversion factors (compare conversion figures shown in brackets in Table 4). These men are not included in "number of men occupied," Column 3.
"	0.2205 ~ 0.256	44	176	
"	0.260 ~ 0.2953	46	184	
"	0.2992 ~ 0.3346	46	184	
"	0.3386 ~ 0.374	46	184	
"	0.378 ~ 0.4134	46	207	
"	0.4173 ~ 0.4527	46	202	
"	0.4567 ~ 0.5118	46	195	
High Carbon Steel.	0.1968 ~ 0.2165	44	216	The crane-driver of the billet stockyard and the other men of the machine shop (the reel driver and live roller gear fitter) are included in the piece-work rate. The roll grinder and roll turner are paid a special piece-work rate, and the shop attendant has a day rate.
"	0.2205 ~ 0.256	44	185	
"	0.260 ~ 0.2953	46	184	
"	0.2992 ~ 0.3346	46	184	
"	0.3386 ~ 0.374	46	184	
"	0.378 ~ 0.4134	46	207	
"	0.4173 ~ 0.4527	46	202	
"	0.4567 ~ 0.5118	46	195	
Welding Wire.	0.315	46	198	
Mild Steel for Nut Manufacture.	I	47	235	
"	II	47	207	
"	III	47	207	
Boot Iron.	I	47	212	
"	2	47	277	
Steel of square section should be treated as round section of the same area.				

REPORT OF THE PERFORMANCE OF THE DAY SHIFT OF 15-1-29.											
WIRE-ROD MILL.		HOURS									
MEN.	NUMBER.	STIPULATED	ACTUALLY WORKED.	ON LEAVE OR ILL.	BORROWED.	LENT.					
	49	447.	449	18	35	9					
CLASS.		STIPULATED TIME.			TOTAL IN MINUTES.		TIME USED.			WHY DAY RATE	
MARK.	QUANTITY IN TONS.	UNIT	MINUTES PER TON.	SEQUENCE	PIECE WORK TIME.	NUMBER OF WORKMEN.	TOTAL.	P.W. P.W.	AV. DAY WORK.	DAY OR AVERAGE	PIECE WORK RATE?
HIGH CARBON STEEL 0.1968" DIAM.	505	44	4.9	216		5	45		45		GENERAL WORKSHOPS.
LOW CARBON STEEL 0.1968" DIAM.	306	44	4.0	176							CHANGING ROLLS ETC.
OTTO 0.3545" DIAM.	400	46	4.0	184		45	404	3673	-	367	50 MINUTES. 44 MEN.
						50	449	3673	45	367	
								WAGES ACCOUNT.			23550 = 64.0
											367.3

WORKS OFFICE GIVEN ON. (DATE) NAME.	WORKS ECONOMICS DEPARTMENT CHECKED ON. (DATE) NAME.	PIECE WORK EARNINGS 64.0 MIN/HOUR.	WAGES DEPARTMENT CHECKED ON. (DATE) BOOKED ON. (DATE) NAME.

FIG. 45. DAILY REPORT OF PERFORMANCE.

The man-hours worked therefore were

$$441 + 35 - (18 + 9) = 449 \text{ hours}$$

The production was :—

High carbon steel 0·1968" diameter	.	.	50·5 tons
Low carbon steel 0·1968" diameter	.	.	30·8 tons
Low carbon steel 0·3545" diameter	.	.	40·0 tons

From these figures the performance can be calculated as follows : Five of the men, fitters and roll-grinders, had no effect on the output, and these had a time of 45 hours which must be subtracted from the total of 449 hours, giving 404 hours.

Changing rolls took 50 minutes for 44 men or

$$\frac{44 \times 50}{60} = 36·7 \text{ hours.}$$

Subtracting these 36·7 hours from 404 hours, leaves 367·3 hours for piece work (see column P.W.).

The time of 36·7 hours is shown entered in the daywork column. The total sum in piece-work minutes was found by multiplying the quantities produced by the ton sequence times, column 2 \times column 5, which in this case was 23,550 minutes. Time allocated to each man therefore was

$$\frac{23,550}{367·3} = 64 \text{ minutes per hour.}$$

The performance was thus $\frac{64 - 60}{60} \times 100$, or 6·7 per cent. above standard.

If the "minutes per hour" were entered for each man in the wages list, the total gives the whole earnings of the men for the period in question in minutes, and when multiplied by the respective rates gives the earnings in money.

If a man is occupied at various jobs such as shearing or levering, during the period, the proportion of time for each job is multiplied by the appropriate rate for the class of work done.

D. THE COSTING SYSTEM.

In the same way that support for works control is obtained by determining standard performance by time studies, and then

contrasting standard and actual performance in any particular case, so actual costs can be contrasted with standard costs, and this is the theory of modern cost control.

Standard costs can only be built up, however, when the costs for varying output rates and for changing production plans can be calculated in advance. This stage is not yet possible at most iron and steel works, where usually the necessary detailed figures are not available. Therefore a transition method is proposed—namely, costing with “equivalent figures.” The value of this method is that the costs of the whole production unit, when subject to fluctuation in output and programme, can be calculated from a single figure—namely, the unit cost of an “equivalent ton.” In other words, the relation of the costs of each class of wire are calculated with relation to the costs of a particular class, selected to serve as a standard for comparison only.

(1) Development of Equivalent Figures.—If the production costs per ton for two different classes of wire such as low carbon wire 0.1968" diameter and 0.4724" diameter are compared, it will be found that the major part of this cost is dependent on the time necessary for rolling a ton, *i.e.*, “the ton sequence time.” There are other costs which are not dependent on the ton sequence time, but on size and quality, such as power, and wear and tear of rolls.

If all costs are divided into these three groups, time costs, power costs and roll wear costs, there will be a constant relation between the figures in each of these groups corresponding to the classes of wire; if one particular class—it matters little which—is selected for the others to be compared with, the ratios of the different classes to the selected class in the three cost groups can be tabulated.

Further, for the tonnage of various classes of wire produced in any mixed programme can be substituted an *equivalent tonnage* of the selected class, and thus the difficulty of comparing two days' or two weeks' work on account of programme variations will be eliminated. The comparisons will be made on a single figure for each period.

Total production costs can be compared in the same way, and individual costs can be derived from the determined cost of the selected class, by using the appropriate factors.

The total production cost in any period is the sum of :—

that part of the cost dependent on time

+ that part of the cost dependent on power

+ that part of the cost dependent on roll wear.

And in the same way the unit cost or cost per ton is made up of these three parts.

The ton sequence times for all classes of wire are determined by time studies. If these ton sequence times are divided by the ton sequence time of the selected class, a series of ratios (hereafter referred to as time ratios) is obtained that is valid for calculating all the time-controlled costs from that of the selected class. For example, a time ratio of 1.2 obtained in this way for a particular class will mean that all the time-controlled costs for that class will be 20 per cent. higher than those of the selected class.

In the same way, the steam consumptions per ton of the other classes can be divided by the steam consumption per ton of the selected class, and a second series of ratios (hereafter called power ratios) obtained—namely, the ratios of all costs dependent on power consumption.

The wear of rolls depends broadly on the friction in the different passes and the number of passes, and this relation can be expressed by the product of the elongation (the ratio of the length after rolling to the length before rolling) by the steam consumption. The ratio of this product to the corresponding product of the selected class will give the factor (called roll-wear ratio) for calculating the costs depending on roll wear.

It is not suggested, of course, that for roll-wear costs the above is a scientifically correct method; but as these costs are only 4 per cent. of the total cost, it gives a relation that is sufficiently accurate for present purposes. A perfectly accurate distribution would be very difficult, if not impossible to obtain.

The relative figures for this mill are given in Table 9. For example, the figures of class 0.1968" diameter show that time-controlled costs are equal to those for the selected class, and the power and the wear and tear controlled costs are respectively 53 per cent. higher and 3.9 times those of the selected class.

(2) **Division of Class Costs.**—The total production costs of the

mittee of Cost Accounting of the Verein Deutscher Eisenhuettenleute. These individual sections of costs are summarised into three parts. The first contains time costs and includes all wages, production wages, salaries, social service charges, holiday pay, and special additions; also the cost of auxiliary

TABLE 9.
Equivalent Figures.

Class, in.		Depending on		
		Time.	Power.	Wear and Tear of Rolls.
(1)		(2)	(3)	(4)
Low Carbon Steel.	0.1968 ~ 0.2165	1	1.53	3.9
" "	0.2205 ~ 0.256	1	1.26	2.23
" "	0.260 ~ 0.2953	1	1.10	1.41
" "	0.2992 ~ 0.3346	1	1	1
" "	0.3386 ~ 0.374	1	0.95	0.75
" "	0.378 ~ 0.4134	1.11	0.94	0.60
" "	0.4173 ~ 0.4527	1.09	0.89	0.47
" "	0.4567 ~ 0.5118	1.05	0.85	0.37
High Carbon Steel.	0.1968 ~ 0.2165	1.20	2.00	5.12
" "	0.2205 ~ 0.256	1.02	1.70	3.00
" "	0.260 ~ 0.2953	1	1.48	1.90
" "	0.2992 ~ 0.3346	1	1.08	1.08
" "	0.3386 ~ 0.374	1	1.00	0.78
" "	0.378 ~ 0.4134	1.11	0.98	0.63
" "	0.4173 ~ 0.4527	1.09	0.93	0.49
" "	0.4567 ~ 0.5118	1.02	0.86	0.37
Boot Iron.	1	1.11	0.97	0.72
" "	2	1.44	1.13	1.15
Mild Steel for Nut Manufacture.	I	1.24	0.94	0.45
" "	II	1.09	0.80	0.31
" "	III	1.09	0.75	0.20
Welding Wire.	0.315	1.06	1	0.87

services—fuel, light, power for pumps, etc., heating, hydraulic power, compressed air, water, maintenance, spare parts, furnace repairs, laboratory, transport, general works costs chargeable to the mill, despatch and overhead costs. The second part contains all the costs for steam raising for power; and the third part gives the roll costs, including roll turning (wages and materials) and depreciation of stock of rolls.

It is not *quite* accurate to call the first group time costs, and to key them to the ton sequence times. For instance, there

TABLE 10.

Division of the Whole Production Costs, in Time Costs, Power Costs and Costs of Wear and Tear of Rolls.

Class, ins.	Quantity Produced in tons	Equivalent Figure.	Time.	Equivalent Figure.	Power.	Equivalent Figure.	Wear and Tear of Rolls.	Production Costs per ton.	Production Costs per ton.
	g .	f_i .	g_t .	f_k .	g_k .	f_w .	g_w .	$u_1 = f_i \cdot u_t + f_k \cdot u_k + f_w \cdot u_w$.	Relative to Selected Class $= 1 \cdot \frac{u_1}{u_2} \cdot \frac{u_b}{u_b}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Low Carbon Steel	913.35	1	913.35	1.53	1399.00	3.9	3560.00		1.205
High Carbon Steel	496.44	1.2	548.00	2.00	912.88	5.12	2335.00		1.5
Low Carbon Steel	7.85	1	7.85	1.96	9.90	2.23	17.5		1.097
High Carbon Steel	14.32	1.02	14.61	1.70	14.61	3.00	42.96		1.25
Low Carbon Steel	356.14	1	356.14	1.10	392.00	1.41	502.00		1.035
High Carbon Steel	7.63	1	7.63	1.48	11.30	1.91	14.50		1.152
Low Carbon Steel	214.04	1	214.04	1	214.04	1	214.04		$u_b = 1$ Selected Class
High Carbon Steel	6.36	1	6.56	1.08	7.06	1.08	7.06		1.023
Low Carbon Steel	321.46	1	321.46	0.95	305.00	0.75	240.60		0.96
High Carbon Steel	6.23	1	6.23	1.00	6.23	0.78	4.86		0.995
Low Carbon Steel	242.40	1.11	269.00	0.94	228.00	0.60	145.50		1.05
Low Carbon Steel	41.42	1.05	43.50	0.85	35.20	0.37	15.32		0.98
Mild Steel for Nut Manufacture	17.78	1.24	22.03	0.94	16.70	0.45	8.00		1.138
	27.09	1.09	29.52	0.80	21.66	0.31	8.40		1.01
	26.44	1.09	28.82	0.75	19.83	0.20	5.29		1.003
$G_1 = 2788.74$ Part of Time Costs $G_t = 63\%$ $U_t = u_t$ $G_k = 3593.41$ Part of Power Costs $U_k = 33\%$ $U_k = u_k$ $G_w = 7121.03$ Part of Roll Costs $U_w = 4\%$ $U_w = u_w$ $G = 11493.17$ Total Production Costs $U = 100\%$									
									$U = u$ $G = u$ $u_1 = 1.125$ u_b

are small differences in wage costs of the different classes of wire due to differences in manning. It would be possible to take these differences into account if they were separated and a special key calculated, but the additional accuracy obtained would be so small as to be not worth the trouble involved.

The actual costs for this mill cannot be published, but the relation of the three groups in any month can be stated as time costs 63 per cent., power costs 33 per cent., and roll costs 4 per cent., the total production cost being 100 per cent.

(3) Comparing Production.—In order that the production for any period may be judged, or compared with a standard, it is necessary that the production figures for each of the different classes of product should be converted into equivalent quantities of the class selected for comparison—namely, low carbon steel wire, 0.315" diameter. An example of the monthly comparison is shown in Table 10.

The weights of the various classes of wire produced are given, the time ratios, the power ratios and the roll-wear ratios. From this example can be seen how the comparison can be made for any month, whatever the programme happens to be.

The total production for the month given was 2659.15 tons.

(a) When the individual quantities are multiplied by the time ratios and added together, the total equivalent production in the selected class (L.C. 0.315) is found to be 2788.74 tons. If now the total time costs, calculated and indicated above, be divided by this equivalent figure, the equivalent time cost per ton is obtained, and this figure may justly and accurately be used to assess the month's work in relation to a standard, or to any other month's work.

(b) In the same way, by multiplying the individual quantities by the power ratios and adding them together, the equivalent quantity as regards power used of the selected class is obtained, and this is 3593.41 tons. That is to say, if the same power costs had been incurred in rolling only L.C. 0.315 wire, the production would have been 3593.41 tons. The total power costs divided by this figure will give an equivalent power cost per ton that will be truly comparable with a similar figure for any other month, whatever its programme.

(c) Repeating this process with the roll-wear ratios, the equivalent roll-wear production is obtained, and this is 7121.03 tons, and from this figure and the roll-wear total costs

the equivalent and comparable roll-wear cost per ton is obtained.

(4) Unit Costs for Each Class of Wire.—The sum of the time costs per ton, power costs per ton, and roll costs per ton of the selected class gives the total cost per ton of this class.

The cost per ton of any other class can be derived from these figures by using the time ratio, the power ratio, and the roll-wear ratio.

The time cost per ton of the selected class, multiplied by the time ratio of any other class, will give the time cost of the other class; the power cost per ton of the selected class multiplied by the power ratio of the other class will give the power cost per ton of the other class; and the roll cost per ton of the selected class multiplied by the roll-wear ratio will give the roll cost per ton of the other class. The sum of these three part unit costs determined for any class desired will give the total unit cost required of that class.

These unit costs would be entered in column 9 of Table 10, but, as already stated, it is not permitted to publish them; their relative values in terms of the selected class, however, are given in column 10 of Table 7 for comparative purposes. An examination of the figures in this column shows that the costs per ton of the wire produced in the month under review vary from 0.96 to 1.5 of the cost of the selected class—that is from 4 per cent. lower to 50 per cent. higher. The average total cost per ton in terms of the cost of the selected class is 1.125 or 12½ per cent. higher, and it is the figure represented by this ratio that would be obtained by the average method of costing ordinarily used.

(5) Characteristics of Class Costing with Equivalents.—(a) No matter how varied the programme may have been, the total result of production work during any period may be judged, or compared with the result for another equal period, on a single figure—the tonnage of the selected class that is equivalent to the varied tonnage actually produced. This method does not make cost accounting more complicated.

Any variations in unit costs as shown by the equivalent figures compared can be quickly traced. A comparison of the part costs, time, power, and roll wear shows at once in which part it is, and examination of details shows the factor or factors responsible.

(b) It is clear that comparisons made on equivalents in this way are valid, and make the appropriate allowances for the incidence of particularly easy or particularly difficult classes of product. It is evident from Table 10 that average costing as usually practised can lead one's judgment very far astray, since the variation in unit costs amongst the various classes of product is as much as 56 per cent.

(c) If necessary, by the method of equivalent figures, it is possible to calculate, in advance, estimated costs of classes not yet rolled.

From the detailed analysis of work and time studies, the production diagrams can be built up and the ton sequence time determined.

Power and roll wear costs can be estimated by comparison with qualities rolled, taking into account the reduction in section and the temperature.

(d) Finally, this method makes possible a valid comparison of costs and production between different works.

(6) Order Costing and Class Costing Contrasted.—In order costing, fluctuations of production cost are referred directly to individual orders, even though they are not attributable to these orders. Delays and accidental stoppages are charged to the orders during the execution of which they occurred. This makes the costs uncertain, and tends to obscure the effects of the essential elements of the processes, and thus renders more difficult the improvement of processes.

The calculation of costs by the use of equivalents separates the accidentals of production (which are recorded separately as delays) from essentials, and thus permits each to be dealt with in the manner appropriate. Equivalent figures are standard values determined by work and time studies. They represent the inherent conditions of work only if stipulated or forecasted performances are reached. These results will not always be reached, and sometimes they may be exceeded, and the difference will be expressed in the total costs, and, in the method under discussion, distributed proportionally over the individual classes of product.

The selling price of rolling-mill products is usually fixed by agreement, and not by cost. Consequently, except as regards size of orders, costs of particular orders are not really necessary. The effect of size of orders—roll changing, trial pieces, mill

setting, etc.—can be more accurately dealt with by work and time studies than by any method available to cost accountants.

E. PROOF OF ECONOMY

The question of changing the billet size in the mill under investigation from $5\frac{1}{2}$ " square to 4" square could not be completely solved without examining the difference in cost of the billet, and was made the occasion also for an examination of the costs of the other rolled products of the company. At the time of publication of this report the examination had not been completed. Therefore no proof of the success of the proposed improvements could be given, but the principle on which the calculation of economy proceeded could be explained.

Three stages of rationalisation of this mill are possible.

Stage (1).—The mill quota of men could be reduced by seven or perhaps eight men, without requiring mill alterations. At the same time as the time study was made, the generation of power was studied and economies were effected. The combined result was a reduction in cost of production of about 9 per cent.

Stage (2).—By the substitution of a 4" \times 4" billet to increase the output, and the mechanisation of the mill, there would be a further reduction of cost of 15 per cent. This was dependent on the smaller billet being obtained at the same price as the larger, and this seemed to be possible.

The profit from this improvement would be sufficient to pay the cost of mechanisation in about a year and a half.

Stage (3).—The cost of production that would result from the electrification of the mill drive and the mechanisation together were calculated. This calculation showed that the investment cost of the electric drive and mechanisation would be recovered in one year.

The total result would be a reduction in cost of production of about 28.5 per cent. as compared with the original cost in the mill, and a decrease of about 21.5 per cent. as compared with stage (1), for which no new capital was required. There was also a further saving, not included in this calculation, of £3250 per annum due to the more economical loading of the turbo-generators in the central power-station, and if this saving were taken into account, the investment cost of the reconstruction would be recovered in nine months.

WORK AND TIME STUDY IN A JOBBING FORGE

THE work of the small forge, to which this case refers, consisted for the most part of the making of forgings to orders or contracts obtained, and each of these orders was an isolated transaction with no guarantee or certainty of a repetition at any time. It will be apparent that under this condition there could, broadly speaking, be no question of special plant or appliances except dies and small tools, whose cost could be covered by the price received for the work; and the cost of any investigation must also be recoverable from the particular job that it referred to.

The present case was a forging for a railway wagon drawbar hook (Fig. 46); these forgings were purchased from time to time by the railway companies or wagon-builders, but always by competitive tenders. This forging had been made in small numbers in the past, but always unprofitably, and when an opportunity occurred to take a large quantity order, and a decision had to be made whether to take it or not, the production engineer was asked to investigate and report as to the possibility of reducing the cost.

The following is a description of the study he made, and of experimental work done, and can be regarded as a fair example of rationalisation of jobbing work in a shop where jobbing was the rule.

The operations could be divided into two main groups, of which the first was the preparation of the "use" or blank from a billet, reheating, drop stamping the head under a Bêché hammer; the second group included chipping off the flash produced in drop stamping, and then the further reheating and the completion by forging under an 11-cwt. steam hammer.

The average output from the first group had been about 187 forgings per 8-hour shift, and from the second group about 38 per shift.

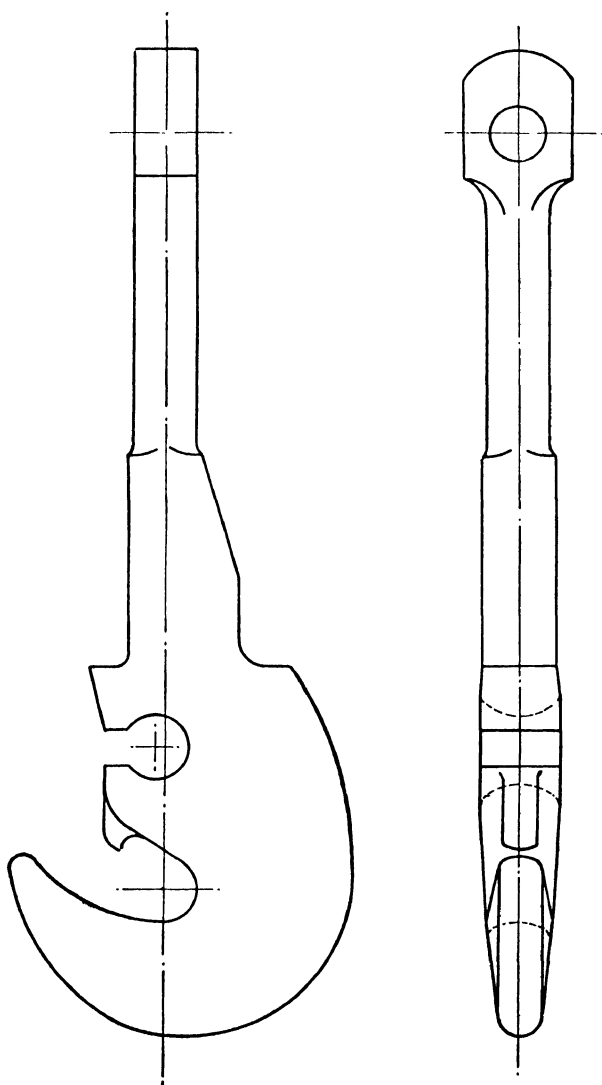


FIG. 46. DRAWBAR HOOK.

At this time the Bêché hammer was a comparatively new tool in the shop, and this part of the work had in consequence already received considerable attention and it was thought had been improved nearly as much as possible. In these circumstances the second group of processes seemed to give a more promising field for study, and it was therefore decided to examine these more closely.

The cost of each forging was as follows :—

	Material	47.52 <i>d.</i>
1st Group.	Production of "use."	
	Reheating and stamping :	
	Wages	3.17 <i>d.</i>
	Dies	5.00
	Overhead costs	15.63
2nd Group.	Chipping and operations under 11-cwt. hammer :	
	Wages	8.25
	Overhead Costs	19.00
	Total	<u>98.57<i>d.</i></u>

In order to estimate the possibility of economy in the second group of processes, cost curves were plotted to show the effect on the total unit cost of increased output per shift, and consequent lower effect of overheads.

The first of these, Fig. 47, related to the first group of operations, and showed that the cost of the product of this group, which formed the material for the second group, varied from 76*d.* per unit at 140 per shift to 67.3*d.* per unit at 240 per shift, and that the cost at the average rate of output of 187 per shift was 71*d.* per unit.

Applying these material costs for the second group of operations, Fig. 48, corresponding total cost curves were obtained that showed the variation in cost with variation in output from this group of operations. Thus for the output of 38 per shift, the previous average, the cost varied from about 93.5*d.* to about 103.5*d.*, according to material cost; and for an output of 53 per shift it varied between about 88*d.* and about 98*d.* per unit, according to material cost.

The work was then studied and timed for a complete shift, and it was found that the output of finished hooks was 32, but, in addition, certain work was done on others that was considered (by time equation) to be equivalent to a further 4

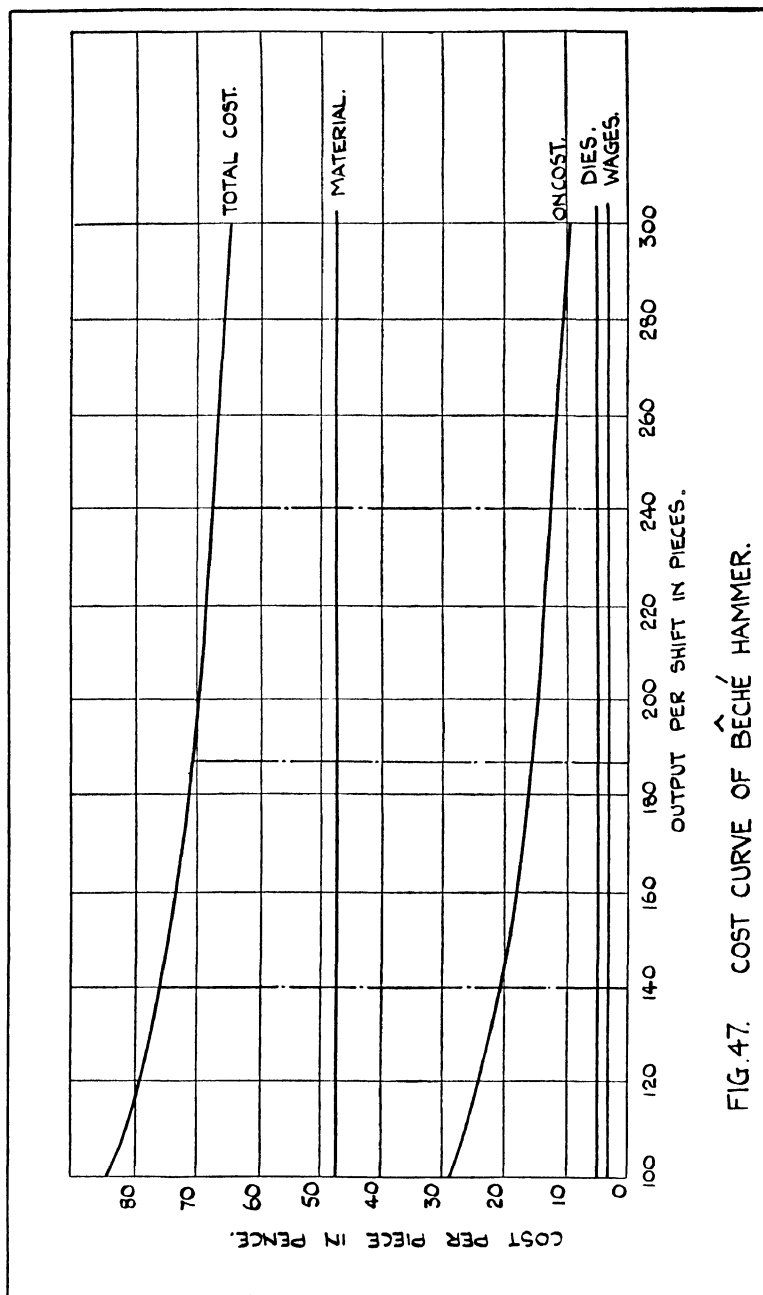


FIG. 47. COST CURVE OF BÉCHÉ HAMMER.

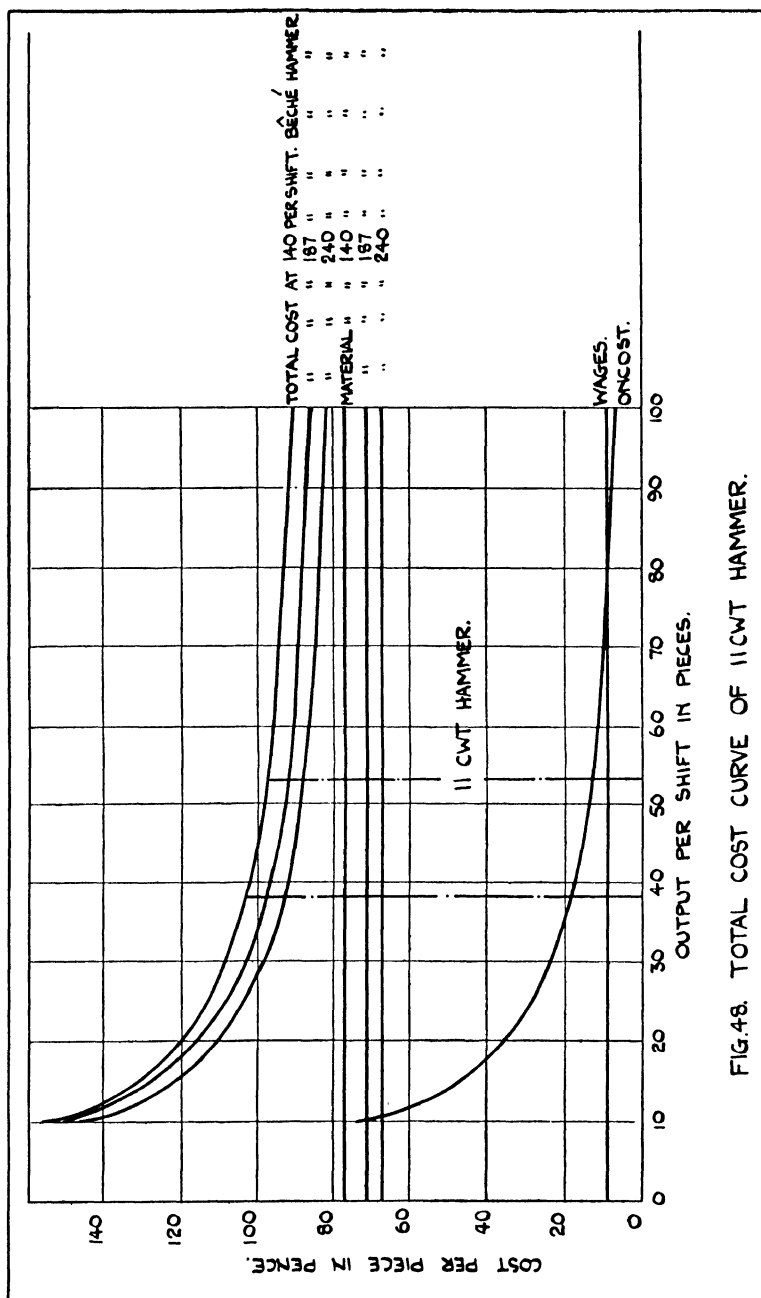


FIG.48. TOTAL COST CURVE OF 11CWT HAMMER.

finished hooks, making 36 in all. The lost time was analysed with a view to reducing it, and found to consist of such items as "waiting for instructions" or "setting gauges," "fetching material," etc.

From the analysis of the observations made, it was judged possible, if the chipping were made a separate operation, to obtain an output of 53 hooks per shift, and the resulting reduction in cost would be 5.23*d.* per hook.

Before making a second trial, a certain amount of reorganisation of the working place was undertaken—a sling for handling the hooks provided, necessary tools placed in convenient places, chipped "uses" supplied, furnace charged with material in advance so as to be heated at the commencement of the shift, and, in addition, a slight change in the shape of the forging was made.

The men were told that their piece-work rates were not in question, and would not be lowered in any case, and therefore they had nothing to lose, and something to gain by increasing their output, and then a second trial was made, lasting for two shifts. The outputs for these two shifts were 41 and 42 hooks respectively.

The principal items of lost time now were "waiting heat," on account of the increased output, and the following further changes were made :—

- (1) It had been noticed that the furnace had not been charged with material quite regularly, and a time schedule was therefore given for this.
- (2) The capacity of the furnace was increased by the provision of a shelf.

A programme was drawn up for a production time of 7½ minutes per hook with the following allowances per shift :—

15	minutes	to prepare tools.
30	„	rest in ten minute intervals.
20	„	mealtime.
18	„	time booking.

Under this arrangement it was intended that hooks should be made in batches of 6, 16, 12, 12 and 7, with rest or meal

intervals between, but this arrangement was modified at the request of the men. They wished to rest at shorter intervals, so it was arranged that they should rest after every 6 hooks and take 40 minutes for their meal.

Under these arrangements the following were the outputs per shift on four and a half days' work :—

Day.	Shift.		
	Morning.	Afternoon.	Night.
Tuesday	50	48	50
Wednesday	50	48	50
Thursday	51	35	51
Friday	50	45	50
Saturday	33	—	—

The forgerman on the afternoon shift was new to the job, and therefore his output was lower than the others ; moreover on Thursday afternoon there was a breakdown which reduced it further. The allowance of $7\frac{1}{2}$ minutes per hook was found to be unnecessarily large ; on the other hand, the men took longer rest periods than had been arranged.

The following gives the average unit times and average rest periods in each shift and on each day :—

	Unit time per hook, mins.	Unit time per rest period, mins.
MORNING SHIFTS.		
Tuesday	6·36	11·0
Wednesday	6·02	12·7
Thursday	6·04	13·0
Friday	5·79	12·8
Saturday	5·93	8·0
AFTERNOON SHIFTS.		
Tuesday	6·98	7·0
Wednesday	7·20	8·0
Thursday	7·23	8·0
Friday	7·32	6·5
NIGHT SHIFTS.		
Tuesday	5·84	9·0
Wednesday	6·30	9·0
Thursday	5·84	10·8
Friday	5·84	11·1

These results indicated that the work could be done at the price at which it was offered and with a margin. In the subsequent execution of the contract the increase in output amounting to 39 per cent. of the previous record and reduction of cost of 5·3 per cent. were maintained.

This last figure, reduction of cost 5·3 per cent., seems to be small at first sight, and hardly worth the trouble that was necessary to obtain it. This, however, is not quite the whole story; the men were affected beneficially, as well as the firm, and the benefits to both might be stated as follows :—

(1) From the Company's point of view, this reduction of cost converted a small loss into a small profit per piece, and a contract for a large number of pieces was taken that would have been allowed to pass. This in itself would have been bad both for the standing of the company and for the morale of its employees.

Moreover, the profit, small per piece, was substantial on the whole contract. Also the job contributed considerably to the overhead charges, which were incurred whether the job was taken or not, so that the profit by taking the job, as against letting it pass, was much greater than the figure 5·3 per cent. indicated.

(2) As far as the men were concerned, since their piece-work prices, according to promise, were left unaltered, their earnings increased in direct proportion to the increase in output—namely 39 per cent., without any unreasonable increase in the working stress or fatigue.

(3) Remembering that this result was obtained by trustful co-operation between management and workers, it meant that both learnt a useful lesson that was capable of becoming a precedent.

On the whole, therefore, this was much better than acknowledging defeat, and was really a very satisfactory result.

CYLINDRICAL GRINDING TO LIMITS : DETERMINATION OF PERFORMANCE TIMES

THE first step in organising work in a machine shop is the designing of tool forms, and the fixing of cutting speeds, depths of cut, and rates of feed for all machines and all the different classes of work. This should be done at the beginning and the data be tabulated, the information being furnished to the workers on instruction cards, instead of leaving these particulars to be decided haphazard while the work is being done. The cutting speed depends on the metal used for cutting tools and the metal being processed. The depth of cut and feed, if for rough cutting—that is, when the maximum effect is required—will depend on the strength of the machine and power of drive, and size and strength of piece being operated on; if finishing, on the material being processed and the quality of finish necessary.

When the necessity for determining piece-work rates was recognised in German industry, the metal working trade was the first to develop methods; and the first step was the determination of all such fundamental data for use in further work. This was done for all the different processes used in their works, such as turning, drilling, planing, grinding, punching, forging, casting, etc. Individual works, of course, made their own work and time studies, and the following case (in extract) is taken from the publications of the “National Committee for Work Studies (Reichsausschuss für Arbeitsstudien—Refa),” and is on the subject of grinding.

It is neither necessary nor possible to give complete details, but the description given below will convey a general idea of the work to be done in such a case, and will be sufficient to show the application of the principles explained in Part 1 of this book and to act as a guide for similar work.

Definitions.—By grinding is meant the removal of material

by means of an abrasive wheel, which is a tool made of granular abrasive material held together by a suitable binding compound. There are, of course, different classes of grinding as :—

Limit grinding.

Tool grinding.

Buffing or fettling, etc. (for instance removal of dead heads, burr, centre taps, etc.).

Burnishing (polishing).

Limit grinding is again divided into external cylindrical grinding, internal cylindrical grinding, and surface grinding. The subject of this example is the first of these—namely, external cylindrical grinding.

Analysis of Work.—First it is necessary to “analyse the work,” which is, in this case, to prepare a descriptive list, in chronological order, of all the motions and operations. The adjustment time—that is, the time necessary to set up the machine and auxiliaries—enters into the calculation once only for each order. The time of working on each “piece,” or “piece time,” is included as many times as there are pieces. Both adjustment and piece times consist of basis and lost times, as described in the chapter on Work and Time Studies, and the second of these, lost time, is taken as a percentage of the first, which is determined. The basis element of the piece time again consists of main time—in this case actual grinding time—and supplementary time. The principle and method of making this analysis of work will be clear from the following example :—

ANALYSIS OF WORK

ADJUSTMENT TIME (to be calculated once for each order).

Adjustment Basis Time.

Preparation of work.

- (1) Receive order.
- (2) Obtain drawing.
- (3) Read drawing.

Procuring tools.

- (4) Obtain clamping tools.
- (5) Obtain gauges.
- (6) (Obtain grinding wheel).

Setting up for clamping.

- (7) Set carrier.
- (8) Set tail stock.
- (9) Set head stock.

ADJUSTMENT TIME—*Adjustment Basis Time—continued.*

Setting up machine and tools.

- (10) Set job speed.
- (11) Set longitudinal feed.
- (12) Set stops.
- (13) (Tighten up grinding wheel).
- (14) True the grinding wheel first time.
- (15) Set grinding wheel carrier.
- (16) Set cross feed.
- (17) Set up steadies.
- (18) Adjust steadies.
- (19) Set swivel table.
- (20) Start
- (21) Grind
- (22) Stop
- (23) Gauge
- (24) Set up splash plates.

} to test for roundness.

Adjustment Lost Time (a percentage of basis time).

PIECE TIME (to be multiplied by the number of pieces, except (25) to (30 below).

Piece Basis Time.

Supplementary Time.

Truing the wheel (this is to be done after a number of work-pieces have been ground, which number depends on the nature of the pieces).

- (25) Clamping diamond holder.
- (26) Slide the table.
- (27) Start wheel.
- (28) True wheel.
- (29) Withdraw wheel.
- (30) Unclamp diamond holder.

Clamping.

- (31) Pick up job.
- (32) Clamp carrier.
- (33) Clean centring holes.
- (34) Oil centring holes.
- (35) Set job between centres.
- (36) Push in tail spindle.

Setting up.

- (37) Start cooling system.
- (38) Engage main drive.
- (39) Start longitudinal feed.
- (40) Start grinding wheel.
- (41) Start cross feed.

Main Time.

- (42) Grind.

Supplementary Time.

Setting up.

- (43) Withdraw cross feed.
- (44) Withdraw grinding wheel.
- (45) Withdraw longitudinal feed.
- (46) Disengage main drive.
- (47) Disconnect cooling system.

Gauging.

- (48) Gauge.

PIECE TIME—*Piece Basis Time*—continued.

Clamping.

- (49) Release tail spindle.
- (50) Remove job from centres.
- (51) Unclamp carrier.
- (52) Lay aside job.

Lost Time (calculated by percentage addition).

- (53) Oil machine.
- (54) Correct trouble, etc.

Adjustment Basis Time.

Setting up for clamping.

- (55) Take down splash plates.
- (56) Put carrier safely away.

Procuring tools.

- (57) (Take down grinding wheel).
- (58) (Take grinding wheels to store).
- (59) Take gauges to store.

Preparing work.

- (60) Take drawing to store.
- (61) Advise completion of job.

Adjustment Lost Time, and Lost Time.

- (62) Conversation with foreman and waiting at stores.
- (63) Completing wage ticket.
- (64) Personal needs, etc.

No further explanation of this part of the work is necessary. It may, however, be pointed out that the first truing-up of the wheel before every grinding order is calculated as part of the adjustment time. Later on, during the grinding work, the truing-up of the wheel is considered as belonging to supplementary time in the form of a periodical supplementary time, *i.e.*, it occurs and is allowed after a certain number of work-pieces have been ground, which will be decided according to the nature of the work-pieces.

This is an instance of how the same operation is necessary and allowed for at different stages of the work; whether different values are used or not will depend on the circumstances of the individual case. For instance, in this case it may be that for the first truing-up of the wheel a longer time is taken—the workman not being accustomed to it as well as he is later on—than for the later repeated truing-up.

This example of an “analysis of work” is given in detail so that a clear understanding may be obtained of the preparatory work necessary before the essential determination of time begins.

DETERMINATION OF TIMES

When the necessary analysis has been made, the collection of figures in the workshops, by one of the four methods (estimating, calculating, time studies, or comparing), is commenced.

First the adjustment basis times must be determined. In our example they are divided into four parts: preparation of work, procuring tools, setting up for clamping, setting-up machine and tools. If a fifth part "special work" is added, this subdivision may commonly cover all kinds of work in adjustment basis time for limit grinding. According to existing factory conditions, it is possible to determine the value of each of these four main divisions of work as a function of variables affecting the adjustment time.

Adjustment and Supplementary Times.—The figures for all different operations, motions or units of motions constituting the enumerated main divisions of work are collected in tables or graphic diagrams in a clear manner, and these tables are called "development tables." It would be too complicated to use them in that state for practical application, and they are consequently contracted to "working tables." This contraction must be done in such a manner that groups of operations or motions which are associated together in practice can be taken from the table as one figure. For instance, one diagram shows the adjustment basis time for "testing for roundness" (Nos. 20, 21, 22, 23, of the analysis of work) as a function of the length and of the diameter of the part in question. How far this contraction may advantageously be carried cannot be established in a general way. It depends entirely on the circumstances of the individual case.

Substantially the same method described for adjustment time is used for supplementary time.

Calculation of Main Time.—Main or cutting time, however, can in this case be differently treated. The time taken is fixed automatically by the machine, and is therefore capable of calculation from data concerning the features of the machine, the dimensions of the job, and other data that have been tabulated previously, with regard to speeds, cuts and feeds, and should be sufficiently comprehensive to cover the whole

range of machines and work to be done in the particular shop. It is described in some detail (below), so that the method may be understood by those not familiar with grinding practice.

Main time	= Number of traverses or cuts \times $\frac{\text{Total travel}}{\text{Travel or feed per minute.}}$
Number of cuts	= $\frac{\text{Grinding allowance (amount to be removed)}}{\text{Depth of each cut (amount removed per traverse).}}$
Total travel	= Length to be ground + length travelled whilst reversing.
Travel or feed per minute	= Feed per revolution of work \times number of revolutions per minute of the work.

These various quantities are determined as follows :—

(a) The grinding allowance is obtained from the work itself, and amounts to half the difference between the diameter of the work as it is, and the diameter it must be when finished.

(b) The depth of cut depends on the diameter and grade (coarseness and cutting quality) of the grinding wheel and the size and power of the machine; generally a machine will be built to take a certain size of wheel, and this, together with the maker's specification of the abrasive wheel, will fix the maximum speed of the wheel; the maximum permissible cuts and feeds should be established and tabulated once for all; if the piece is being rough ground, maximum permissible cuts will be used, but for finishing cuts the depth of cut will depend on the finish required.

(c) The number of revolutions per minute of the work will depend on the diameter of the work and the economical cutting speed for the wheel used (previously established and tabulated); the machine will have a range of speeds (unless it is specially built to take a specific size, or small range of sizes, only), and this limits the selection.

(d) The feed per revolution of the work will also depend, like the depth of cut, on the diameter (and perhaps the thickness) and grade of wheel, the size and power of the machine, and the finish required; the feed will have a definite relation to the depth of cut, since some jobs will be ground with a heavy cut and slow feed, others with a light cut and quick feed; for a high finish, cut will be light and feed very slow. The machine will have a range of feeds for selection.

The total distance travelled for each cut will depend both on the job and the machine. It will amount to the length to

be ground, plus the breadth of the cutting face of the wheel, plus twice the length travelled while reversing. This latter will depend on the design and condition of the machine, and generally must be determined by measurement; in the case of machines with hydraulic feed it is usually so small that it may be neglected.

In a thoroughly organised shop, this calculation of cutting time, together with the speeds and feeds to use, and the grinding wheel to mount, would be given on the instruction card for the job.

It is evident from the above that a considerable amount of tabulated information is necessary, especially if there is a great variety of machines in the shop; this information will have to be revised as technical progress of one kind or another is made, so that the shop practice may always be up to date.

Examples.—These are selected because of their simplicity, from the ordinary work of a modern factory, and the results obtained are quite normal.

Hardened gudgeon pins with a parallel shank $\frac{1}{16}$ " diameter and $2\frac{1}{8}$ " long, made of chrome steel, are to be ground and polished. The tolerance on the diameter is $+0.0005$ ". The diameter is to be reduced by between 0.0138 " and 0.0158 "—that is, the grinding allowance, as previously defined, varies between 0.0069 " and 0.0079 ".

Time studies were first made of the work as it was carried out before the investigation. This manner of production can be divided into two parts: Ia, grinding, and II, polishing. The different operations are :—

- Ia (1) Put pins on mandrel.
- (2) Grease.
- (3) Clamp.
- (4) Start the machine.
- (5) Start grinding wheel.
- (6) Rough grind.
- (7) Test.
- (8) Final grind.
- (9) Disengage.
- (10) Unclamp.
- (11) Lay aside.
- (12) True up the wheel (once after 20 work-pieces).

It is found that the average main time per work-piece is 7.65 minutes, and that the average supplementary time is 0.79 minute.

- II. (1) Clamp.
(2) Polish.
(3) Stop machine.
(4) Unclamp.

The average main time in this case is 0.80 minute, and the average supplementary time is 0.41 minute per work-piece.

Therefore Ia and II together : $(7.65 + 0.8) + (0.79 + 0.41) = (8.45 + 1.20) = 9.65$ minutes. The lost time in the workshop in question was 15 per cent. of the basis time, in this case = 1.45 minutes. The whole piece-time therefore was 11.10 minutes. The machine tool used in process Ia was a small cylindrical grinder, and in II a polishing machine. During the investigation it was established that the workman did not use the automatic drive of the table and the automatic cross feed, and this fact caused the main times for rough and final grinding to be disproportionately long—namely, 7.65 minutes. At first sight it seems strange that the workman did not use these automatic motions, but made his work more arduous by working by hand alone.

In making investigations of this kind, however, it is often found that the workmen are either insufficiently familiar with the construction of their machines, or do not understand the purpose and value of various features of the design, and consequently do not use the machines to the full advantage. Often, where an old pattern of machine has been discarded and a more modern type substituted, the workman uses the new machine exactly as he used to work with the old one, and the advantage of the substitution is completely lost. This illustrates one of the valuable features of these studies, especially where the foreman is a "busy" man.

The first step in rationalisation was to increase the working speed by using the two automatic appliances. By this means the processes according to Ia are transformed into those according to Ib, which need not be enumerated again because the subdivision of the work has not been changed.

It was found that all the divisions of time were reduced, not

only the rough grinding time as would be expected, but also the finish grinding and supplementary times. The rough grinding time is reduced by the greater continuity of the automatic feeding as against the hand feeding; the finish grinding is reduced by the fact that the automatic cross feed (depth of cut) gave a greater depth of cut than the hand cross feed when roughing, and thus left less material to be removed by the finish grinding; the supplementary time is shortened, probably because the quicker automatic speed of the machine tool influenced the workman in such a manner that he unconsciously did his part of the work at a quicker rate. These gains are indeed partly counterbalanced by the fact that a longer time is necessary for truing up the grinding wheel, which is more quickly worn out when the automatic feed is used. The total result for Ib and II together gives—

Average main time 3.62 minutes instead of 8.45.

Average supplementary time 1.13 minutes instead of 1.20.

Inclusive of lost time at 15 per cent. of the basis time, *i.e.*, 0.75 minute, the whole piece time equals 5.50 minutes.

The second step of rationalisation was to arrange that the whole process II, the polishing, was done during the main time of the rough grinding. This takes 1.95 minutes, and is a completely automatic process; during this time, the polishing, which only took 1.21 minutes, could easily be done if the polishing machine were so placed that the workman on the cylindrical grinder could look after work on both machines.

This was possible of arrangement in the workshop in question, and the result was process III, with:—

Average main time 2.82 minutes.

Average supplementary time 0.72 minute.

Lost time 15 per cent. of the basis time 0.56 minute.

Whole piece time 4.10 minutes.

Later on there occurred a new possibility of reducing the piece time, when a centreless grinding machine became available for the rough grinding, and a lapping machine could be used for the polishing.

The process of centreless grinding (IVa) demands an initial

adjustment time that was not necessary for Ia, for Ib, or for II, and therefore was not required for III.

This work is as follows :—

Rough Grinding.

- (1) Remove material supply chute.
- (2) Set the feed wheel at 4 degrees.
- (3) Set the scale of the diamond carrier of the wheel at 4 degrees.
- (4) Start the motor.
- (5) Change the number of revolutions to 420.
- (6) True up the speed wheel three times.
- (7) Change the number of revolutions to 14.
- (8) Withdraw the feed slide.
- (9) Put in a pin.
- (10) Set up the rest on which the pins slide.
- (11) Advance the feed slide.
- (12) Replace the material supply chute.

The adjustment basis time for rough grinding under these conditions was measured, and found to be 14.05 minutes.

The work to be done in adjusting for final grinding is practically the same, and with sufficient accuracy the same time can be taken. The whole adjustment basis time is, therefore, $2 \times 14.05 = 28.10$ minutes, and with an addition of 15 per cent. = 4.20 minutes for adjustment lost time, the adjustment time is determined as 32.30 minutes.

The work for centreless grinding itself was for :—

- (1) True up the wheel.
- (2) Allow test pin to run through.
- (3) Gauge.
- (4) Start grinding wheel.
- (5) Allow pins to run through.
- (6) Gauge.
- (7) Take the delivery container with pins back to the starting point.

This work is done, in the example under discussion, seven times to reduce the diameter of the pins to the specified size, because the centreless grinding method removes only a little material at each pass. The basis time was determined as

0.56 minute per pin and, with lost time added, as 0.580 minute.

On the lapping machine in the polishing of the pins there was an adjustment basis time with the operations and motions given below :—

- (1) Fit the work holder on the machine.
- (2) Clean the lapping wheels.
- (3) Prepare grinding material.
- (4) Put grinding material on the wheels.
- (5) Set up the upper wheel.
- (6) Final lapping (I) of the lapping wheels.
- (7) Put on grinding material, set up the upper wheel.
- (8) Final lapping (II) of the lapping wheels.
- (9) Put on grinding material, set up the upper wheel.
- (10) Final lapping (III) of the lapping wheels.
- (11) Take back the upper wheel.
- (12) Clean.
- (13) Insert eccentric for the holder of the job.

The total time for this work was found to be 22.26 minutes, and with 15 per cent. addition for adjustment lost time, the adjustment time becomes 25.5 minutes.

The work to be done in the basis time was :—

- (1) Place the pin on the work holder.
- (2) Attach the clamps.
- (3) Attach the work holder.
- (4) Put on grinding material.
- (5) Set up top shield.
- (6) Lapping.
- (7) Unfasten the clamps and remove the job.
- (8) Lay aside the pins.

The basis time was 1.09 minutes, and with 15 per cent. addition for lost time, the piece time was 1.25 minutes. The piece times for the processes IVa and IVb were added, and the whole piece time using the centreless grinding and lapping machines was found to be $0.58 + 1.25 = 1.83$ minutes; with this method of work was connected the further advantage that the quality of the product was better. The accuracy of dimensions and smoothness of surface obtained in this way

are greater than they can be when using an ordinary cylindrical grinder and an ordinary polishing machine. Before different methods can be finally compared, it must be noted that using the processes I, II and III it is necessary to prepare the pins in centring machines, which was not required in the process IV. This centring work took, as time studies show, 4 minutes per work-piece. Now the differences can be seen clearly in the following table.

Process.	Ia. II. Work before rational- isation, grinding by hand.	Ib. II. Grinding with automatic feed.	III. Grinding after displacing the polishing machine.	IVa. Centreless machine.	IVb. Lapping machine.
Centring	4.0	4.0	4.0	—	—
Adjustment time	—	—	—	32.5	25.5
Piece time	11.1	5.5	4.1	0.58	1.25
				1.83	
Total time for 100 pieces	1,510	950	810	58 + 32.5 + 125 + 25.5 = 241	
Total time for 1000 pieces	15,100	9500	8100	580 + 32.5 + 1250 + 25.5 = 1888	
For 1 piece	15.1	9.5	8.1	Producing 100 pieces 2.41 min. Producing 1000 pieces 1.89 min.	
Percentage sav- ing against process III	—	—	—	Producing 100 pieces 70% Producing 1000 pieces 76%	
Percentage sav- ing against process Ib + II	—	—	15%	Producing 100 pieces 74.6% Producing 1000 pieces 80.1%	
As against pro- cess Ia + II	—	37%	46.4%	Producing 100 pieces 84.0% Producing 1000 pieces 87.5%	

This example shows what savings are possible by changing the production methods without investing new capital (*see Ib + II and III*); also what saving can be made by investing new capital in centreless grinding and lapping machines,

(IVa + IVb), and it may be repeated that this example as regards the savings effected is quite a normal one.

It must not be forgotten, however, that the percentage figures given above do not show the real reduction of costs. They form only the foundation for a real cost accounting in which all charges, including depreciation of machine tools, use of tools, etc., as they occur in the different processes, are taken into account. It is not necessary for the purpose of this example to go further into this aspect of the matter, but it is necessary to mention it in order to point again to the close connection between time studies and cost accounting, and then to ensure that the incomplete result given above does not produce a false impression. It may be, for instance, that the cost of depreciation will invert the result against the centreless grinding machine. That depends, however, on the working conditions of the factory in question. For instance, it is found sometimes that these machine tools work uneconomically because there is not work enough for them in the factory; thus they have to stand idle the greater part of the time, and the depreciation has to be carried by a fraction of the work possible on them.

This may be sufficient to give an impression of the work which has to be done in calculating fair piece-work rates or in fixing standard performance times. If it is remembered that in order to get the best results it is necessary to study every job and every process in the factory in a similar manner to this, it will be appreciated that a very considerable amount of work is involved. For a firm producing motor-cars it was estimated at one time that, at the beginning, an office with sufficient staff and the right man in charge would need perhaps two, or two and a half years, to determine in a proper manner the thousands of piece-work rates or standard times. Moreover, it should not be thought that after this has been done the office can be closed and the staff disbanded. On the contrary, the work must be continually revised in order to take full advantage of all technical progress made, and of improvements rendered possible by the growth of business, and also of the continuous reduction of cost and improvement of quality obtained; this only will ensure the soundness and stability of the undertaking and the industry.

Lost Time.—Finally some remarks may be added on the determination of lost time, which has been assumed above as 15 per cent. of the basis time. It is true that this determination is difficult, and requires proportionally long time studies, and this often means that a guess is made or figures are taken from other factories, when these can be obtained. Figures obtained in these ways may be either too high or too low, and nobody knows which, or by how much. The result is that standard times and piece-work rates are too high or too low, with effects already mentioned.

A time study for common purposes to determine the 15 per cent. in the foregoing example may be described as follows : In a workshop a number of workers are observed, and, on the average, each of them is found in a week of 48 working hours to use for :—

	Min.	Min.	Min.
Waiting for instructions	5	—	—
„ tools	4	—	—
„ material	6	20	—
„ transport or assistance	16½	—	—
Tools getting out	12	—	—
„ locking up	14½	—	—
„ exchanging used	6	—	—
„ sharpening	16	—	—
Entering up figures for wage account	5	—	—
Receiving wage	4	—	—
Interruption by foreman	8	—	—
„ „ other workmen	1	—	—
Personal needs	67	—	—
Fetching food and drink	20	—	—
„ oil and cleaning materials	9	—	—
Machine greasing	15	—	—
„ removing chips	25	—	—
„ cleaning	25	—	—
Minor faults in machine	15	—	—
„ „ belts	40	—	—
„ „ drive	—	15	—
Cleaning bench	29	—	—
„ surface plate	15	—	—
Arriving late	—	—	7
Arbitrary stoppages	—	—	9
Ending too early	—	—	—
Personal conversation with other workers	—	—	6
Total	358	35	22

So the total lost time, 358 + 35 + 22 minutes, is divided into three parts :—

(1) That in which time is lost more or less regularly through no fault of the workman, and for which he must be paid.

(2) That due to occasional occurrences, which must also be paid for, but which, being irregular and not incidental to the process, should not be taken into account for the purpose of the lost time computation.

(3) That which is lost by the fault of the workman and is not paid for.

The total working time according to the contract is $48 \times 60 = 2880$ minutes. $2880 - (358 + 35 + 22) = 2880 - 415 = 2465$ minutes.

Basis time and adjustment basis time or net time for actual work	2465 min.
Lost time unpaid for	22 "
Net working time allowed in contract	2487 "
Regular lost time due for compensation	358 "
Irregular lost time due for compensation	35 "
Total time	2880 "

Percentage for lost time is $\frac{\text{compensated regular lost time} \times 100}{\text{net working time allowed}}$

$$= \frac{358 \times 100}{2487} = 14.4\%, \text{ say } 15\%.$$

To be quite accurate, an investigation should be made in this manner for every workman and every machine tool, and an average value found for the whole group of workers, or the whole workshop, to which it is intended that the same percentage shall be applied. This may be quite a serious task, but the only alternative is to make a lost-time study for each determination of standard times, which, in some cases, is very desirable; for constant efforts should be made to reduce it, especially in the steel trade, where failures in timing, accidents and breakdowns to plant, and lack of balance in production cause delays that are large and costly.

In any case pains should be taken to see that the lost time allowance is fair and reasonable, whether it be determined as here described once for all, or at each study; if an average allowance is decided upon and determined, it should be checked from time to time as conditions in the shop change.

DETERMINATION OF WORKING TIME IN A STECKEL MILL

THE following is another example of the way in which the results of time studies, the particulars of the work, and the characteristics of the machine can be applied to such a purpose.

The Steckel mill is a machine for the cold rolling of steel strip ; it is of the type in which the power is applied to the coilers instead of to the rolls themselves. It consists of a four-high mill with a coiler at each side, and is reversible. (Fig 49). The fact that no provision has to be made for driving the working rolls makes the use of smaller rolls possible, and this has several advantages, the principal of which is that the material is not work-hardened so much, and consequently the intermediate annealings necessary between reductions are much fewer.

The deflection of the rolls at right angles to the strip is prevented by unusually large backing rolls ; there is nothing, however, to stiffen the rolls in a direction parallel to the strip. This fact, together with the tension necessary to draw the strip through the rolls, limits the amount of reduction per pass, but it compels, as it were, the production of strip that is very uniform in thickness, across the width. On the other hand, the mill can run at much higher speeds than an ordinary four-high mill with driven rolls. Generally it is regarded as most suitable for the production of very accurately rolled strip, for very thin gauges, or for the rolling of material that is unusually subject to work hardening.

The deflecting rolls (Fig. 49) that guide the strip from the work rolls into the coiler, and *vice versa*, are cooled by a water circulation.

It will be seen from this diagram that, since the strip remains attached to the coilers until the process of rolling is complete, there is a length of it at each end of the coil that never passes the rolls at all, and consequently is not reduced. This length is

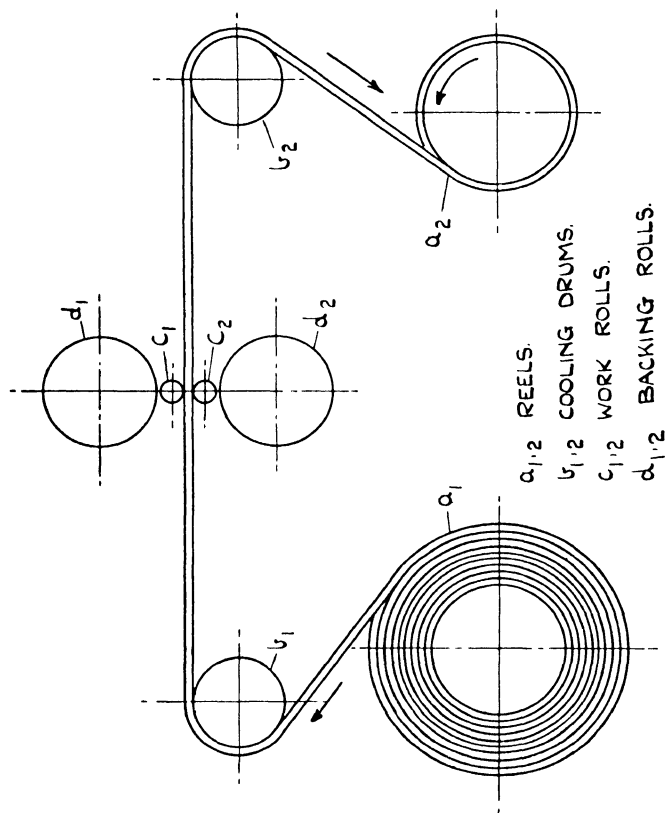


FIG. 49. COLD-ROLLING MILL FOR STRIP BY STECKEL.

waste, and in order that its proportion to the whole may be kept as low as possible, it is desirable to use the greatest weight of coil that can be used. The weight of coil recommended and for which the coilers are suitable is 2000 lb. per foot of width.

In all that follows it is to be understood that any figures given, although actual figures and of proved accuracy in the case to which they refer, are to be regarded as examples, and should not be used for any other case without verification.

The working time of each job on this mill consists of :—

- (1) Starting time.
- (2) Rolling time.
- (3) Reversing time.
- (4) Finishing time.
- (5) Lost time.

Starting Time is occupied in putting the coil on the mill, adjusting the guides, adjusting the rolls and starting the machine.

Finishing Time is consumed in removing the coil from the mill, which, like starting, involves several small operations, such as lifting rolls, releasing strip from empty coiler, cutting off end and attaching to outside coiler, winding strip from full coiler, etc.

Reversing Time is the time taken up in reversing the machine at the end of each pass and in motions incidental thereto, such as adjusting the rolls for the next pass, etc.

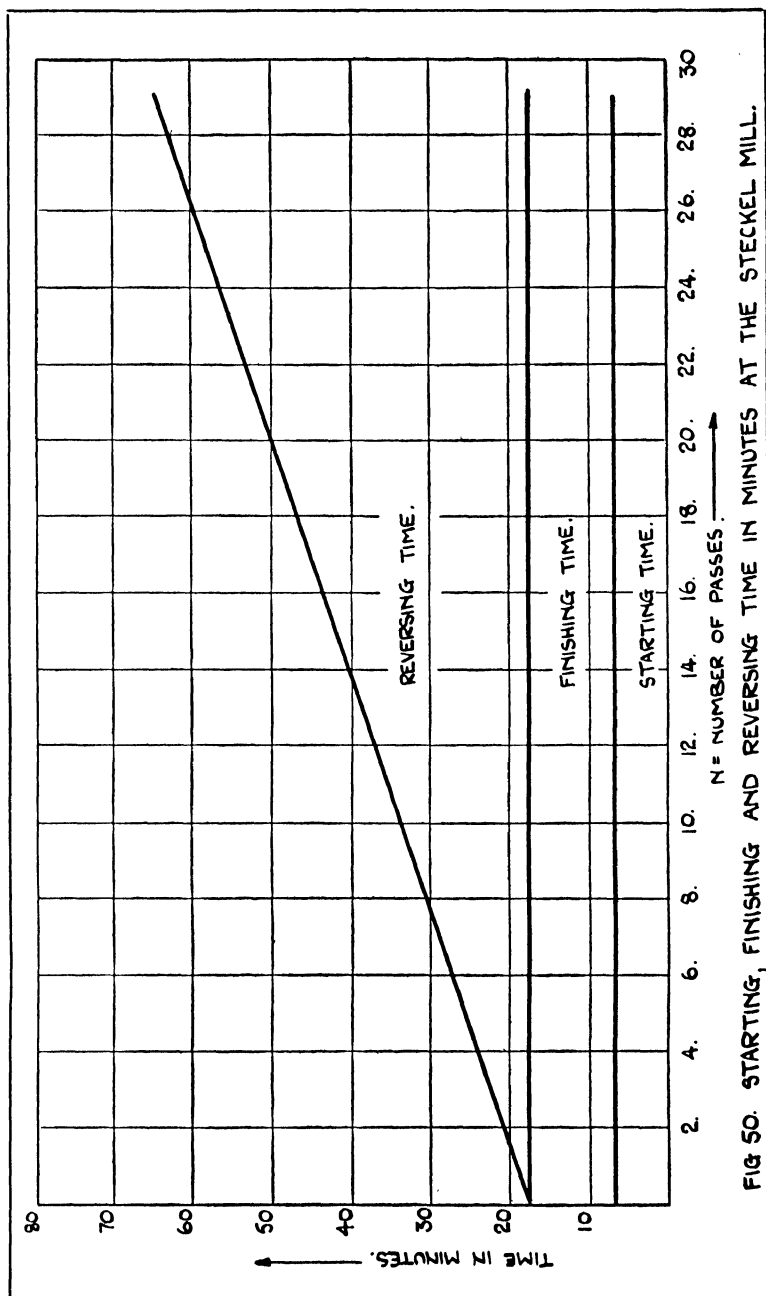
Rolling Time is the time the strip is passing through the rolls and being reduced.

Lost Time, as previously explained, is the time that is unavoidably lost whenever human activity is involved.

Referring these quantities to definitions previously given, the total of these times is *Piece Time*; rolling time is *Main Time*, and reversing time is *Supplementary Time*; starting and finishing times added together are *Adjustment Time*.

Lost time in connection with this mill was found by time studies to be $12\frac{1}{2}$ per cent. of the sum of the other times.

Starting time, finishing time, and reversing time per pass are practically constant, and independent of the nature of the work. Including their respective shares of the lost time, they are found



to be as follows : Starting time, 7 minutes ; finishing time, 11 minutes ; reversing time per pass, 1.6 minutes. The sum of these three times for any job can be taken from the graph Fig. 50, when the number of passes is known. In any particular case, the number of passes can be calculated, assuming a maximum first reduction of 25 per cent. and subsequent reductions varying from 10 to 15 per cent., according to the quality of steel, the power available and the accuracy of gauge (across the strip) required. Or, having determined by experience the average reduction per pass for each of the various classes of steel rolled, a graph similar to Fig. 51 can be constructed.

The rolling time can be determined from Table 11 with the help of the original length l_a of strip. This length l_a can be calculated by the equation :—

$$l_a = \frac{\text{Weight of the coil}}{\text{Width} \times \text{original thickness} \times \text{specific weight.}}$$

It can be taken from suitable tables or from graphs, as shown in graph Fig. 52.

Graphs shown in Figs. 50 and 52 are so simple that it is not necessary to explain how they are made. The construction of graph Fig. 51 and Table 11 will be explained later, after an example is given to show how easy it is to determine the working time of any job with these auxiliaries.

Example.—A coil of 560 lb. weight, of material 3.75 in. wide and 0.083 in. thick, is to be rolled into strip of 0.006 in. thickness. The quality of the material is such that, according to experience, an average reduction per pass of 10 per cent. is suitable.

Graph Fig. 51 extended gives the number of passes, 25.

Graph Fig. 50 gives starting, finishing and reversing time, 58.5 minutes.

Graph Fig. 52 gives original length, 530 ft.

Table 11 gives a factor 0.3625.

Rolling time = original length \times factor

$$= 530 \times 0.3625 = 192 \text{ minutes.}$$

Working time of the job is

$$58.5 + 192 = \text{about } 250 \text{ minutes.}$$

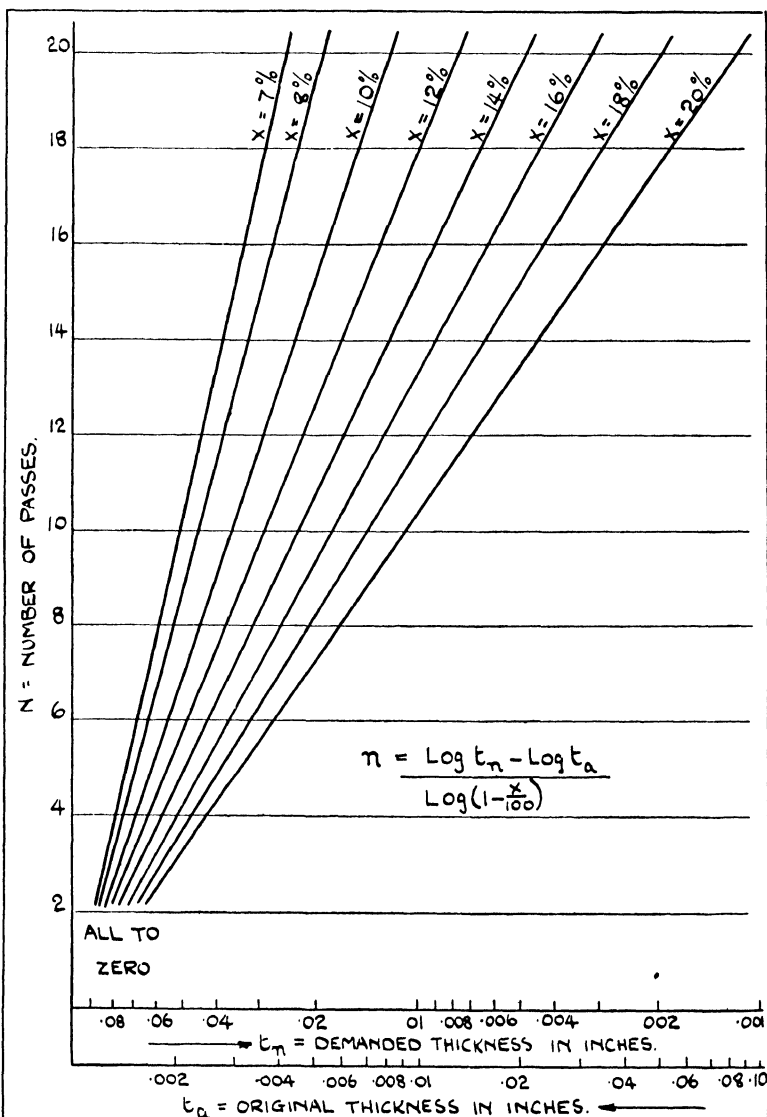


FIG 51 NUMBER OF PASSES ON THE STECKEL MILL AGAINST ORIGINAL AND FINISHED THICKNESS OF STRIP IN RELATION TO DIFFERENT PERCENTAGES OF REDUCTION.

TABLE 11.
Factor for Calculation of Rolling Time at Steckel Mill.

Reduction, %.	No. of Passes.									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
8	0.0031	0.00633	0.00985	0.0141	0.0181	0.0234	0.0284	0.0339	0.0399	0.0480
10	0.0031	0.00660	0.0104	0.0147	0.0195	0.0250	0.0306	0.0369	0.0444	0.0525
12	0.00315	0.00670	0.0108	0.0155	0.0207	0.0269	0.0335	0.0410	0.0498	0.0596
14	0.00325	0.00705	0.0114	0.0165	0.0225	0.0289	0.0376	0.0468	0.0575	0.0703
16	0.00335	0.00730	0.0120	0.0176	0.0242	0.0325	0.0418	0.0530	0.0664	0.0825
18	0.00340	0.00757	0.0128	0.0187	0.0267	0.0363	0.0472	0.0610	0.0778	0.0985
20	0.00350	0.00788	0.0134	0.0198	0.0287	0.400	0.0530	0.0697	0.0905	0.1165

Reduction, %.	No. of Passes.									
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(25)	
8	0.0538	0.0618	0.0728	0.0795	0.0897	0.1010	0.1150	0.1265	0.2535	
10	0.0614	0.0714	0.0855	0.0945	0.1083	0.1235	0.1400	0.1500	0.3625	
12	0.0710	0.0840	0.0985	0.1100	0.1333	0.1545	0.1755	0.2045	0.5270	
14	0.0850	0.1140	0.1210	0.1447	0.1972	0.2035	0.2385	0.2815	0.8225	
16	0.1015	0.1240	0.1510	0.1830	0.2210	0.2665	0.3175	0.3755	1.3400	
18	0.1240	0.1544	0.2145	0.2375	0.2940	0.3520	0.4440	0.5460	2.2500	
20	0.1495	0.1900	0.2420	0.3230	0.3860	0.4850	0.6100	0.7670	2.7050	

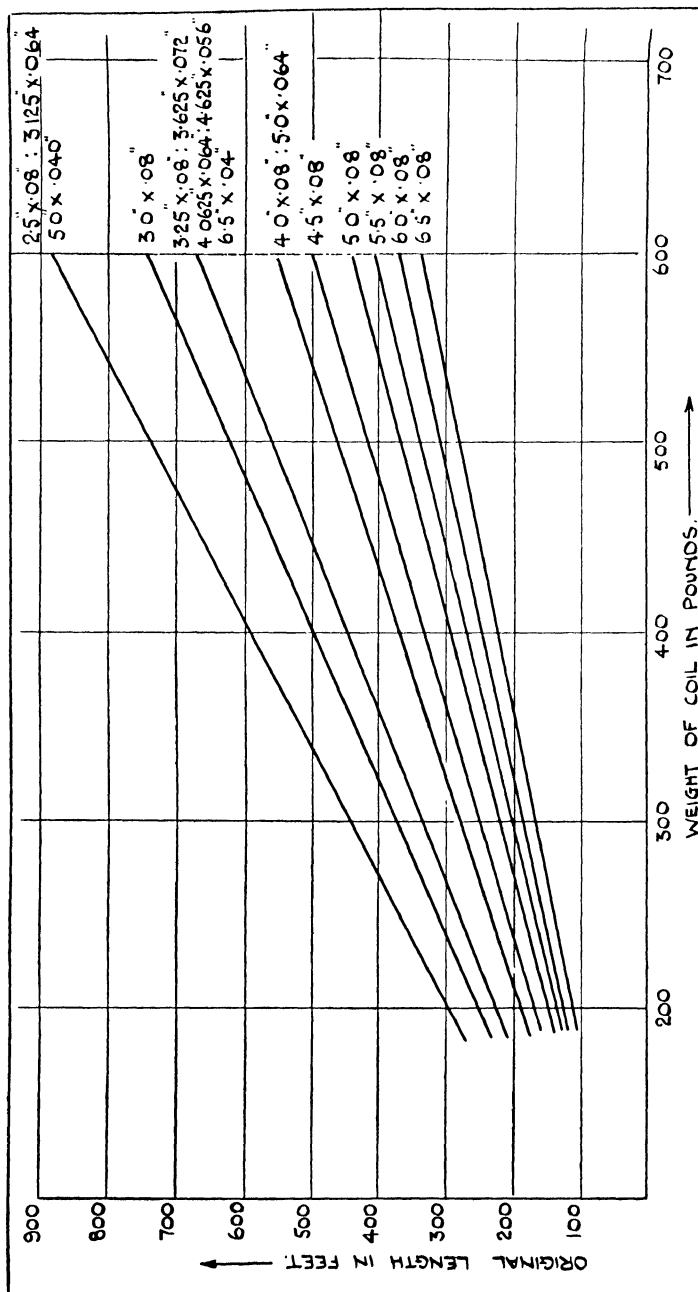


FIG. 52. ORIGINAL LENGTH OF STRIP IN RELATION TO SECTION AND WEIGHT OF COIL.

It should be clear from this example that graph Fig. 51 and Table 11 can be used without understanding how they are built up; but in case this method should be used under different working conditions, it is desirable to understand how the figures are developed. This may be explained as follows:—

If the original thickness is t_a , the thickness after the first pass t_1 , the second pass t_2 , the last pass t_n , and the average percentage of reduction $= x$, we have the following equations:—

$$\begin{aligned} t_1 &= t_a \left(1 - \frac{x}{100}\right) \\ t_2 &= t_1 \left(1 - \frac{x}{100}\right) = t_a \left(1 - \frac{x}{100}\right)^2 \\ t_n &= t_a \left(1 - \frac{x}{100}\right)^n \\ n &= \frac{\log t_n - \log t_a}{\log \left(1 - \frac{x}{100}\right)} \end{aligned}$$

Graph 51 shows this equation.

If the length after the first pass is l_1 , and the thickness t_1 ; after the second pass the length is l_2 , and the thickness t_2 ; after the last pass the length is l_n , and the thickness t_n ; and, if the average rolling speed is V , the equation for the rolling time T_r is:—

$$T_r = \frac{l_1}{V} + \frac{l_2}{V} + \dots + \frac{l_n}{V} = \frac{1}{V}(l_1 + l_2 + \dots + l_n)$$

The volume of the material remains practically unchanged. Therefore

$$\begin{aligned} l_a \times t_a &= l_1 \times t_1 = l_2 \times t_2 = \dots = l_n \times t_n \\ l_1 &= \frac{l_a \times t_a}{t_1}; \quad l_2 = \frac{l_a \times t_a}{t_2} \quad \dots \quad l_n = \frac{l_a \times t_a}{t_n} \\ T_r &= \frac{l_a}{V} \left(\frac{t_a}{t_1} + \frac{t_a}{t_2} + \dots + \frac{t_a}{t_n} \right) \end{aligned}$$

As we have seen above

$$\frac{t_a}{t_1} = \frac{1}{1 - \frac{x}{100}}; \quad \frac{t_1}{t_2} = \frac{1}{1 - \frac{x}{100}}$$

Therefore

$$\frac{t_a}{t_2} = \frac{1}{\left(1 - \frac{x}{100}\right)^2} \cdots \frac{t_a}{t_n} = \frac{1}{\left(1 - \frac{x}{100}\right)^n}$$

By substituting this in the equation for T_r , it is found after some transformation that

$$T_r = \frac{l}{V} \times \frac{1 - \left(\frac{1 - \frac{x}{100}}{1 - \frac{x}{100}}\right)^n}{-\frac{x}{100}}$$

Taking from time studies the lost time as 12.5 per cent. of the other parts of the working time (see above) and the average rolling speed $V = 400$ ft. per min. it is :—

$$\text{Rolling time } T_r = l_a \times \left\{ \frac{1.125}{400} \times \frac{\left(1 - \frac{1 - \frac{x}{100}}{1 - \frac{x}{100}}\right)^n}{-\frac{x}{100}} \right\} = l_a \times \text{factor.}$$

Table 11 gives this factor for the different numbers of passes n , and the different percentages of reduction x .

This method is not a scientific one, but it is very satisfactory in practical use, which is more to the point. There will be a slight inaccuracy due to the fact that the material spreads laterally a slight amount, and not entirely longitudinally as is assumed in the calculation. This error is quite negligible in view of the magnitude of the allowances made.

CHIPPING OF STEEL BILLETS

INTRODUCTION

WHEN molten steel is poured into an ingot mould made of cast iron, the surface of the resulting ingot often has upon it certain blemishes. Some of these are removed in the furnace or soaking pit in which the ingot is prepared for rolling, but, on the other hand, sometimes small bubbles, caused by the evolution of gas, that were previously below the surface are exposed. All of these blemishes are spread over considerable lengths of billet in the process of rolling, and in addition, sometimes, new ones are created by mechanical action of stationary parts of the mill (guides principally) on the (hot) soft steel. If these blemishes or marks were left on the metal, in many cases they would persist and appear in the finished product. In some processes, and in use, these marks would tend to become the origin of more deeply seated faults and flaws, and cracks and breakages would occur.

Unceasing vigilance and care are exercised in casting the ingots, as to temperature of steel, rate of pouring, and surface of ingot mould, in order to minimise this trouble, and, in the same way, care is taken to prevent undesirable contacts in the mill to avoid scratches. In spite of this care, these incipient flaws are to be found on a percentage of the billets or slabs, and they are removed by chipping with pneumatic hammers and chisels. The work is laborious, fatiguing and costly, and cries aloud for replacement by some easier and quicker method, and one more in keeping with modern methods of cutting steel. Attempts to improve the method almost universally adopted are frequent, and here are described certain efforts in this direction. Attempts have been made to increase the rate at which the work was done by fixing piece-work prices based on time studies, but it was recognised that this was not satisfactory, because there was no just way of measuring the work done.

The flaws are irregular in size and in distribution, and the only fair way of measuring the work done in chipping would be to collect and weigh all the chippings, and this is impracticable in a steel works. Moreover, it is inevitable that a certain amount of handling has to be done, or time spent while the material is being handled, and this will vary considerably relatively to the amount of chipping.

In the studies described here, therefore, efforts are confined to obtaining the best appliances, and to measuring the effect of fatigue. The working places had already received a considerable amount of attention as regards the comfort and convenience of the workers.

The Chisels.—(1) **Point Angle.** The first point considered was the shape (point angle) and hardness of the chisel, and a highly skilled and expert chipper was selected for the study. Six different classes of steel were tested, and each billet was weighed on a precision scale before and after chipping.

The following were the kinds of steel selected :—

Mild Steel	A.	Plain Carbon	0.28–0.32%	Brinell Hardness	179
"	B.	B.N. Chrome	0.40–0.45%	"	228
"	C.	Plain Carbon	1.20–1.3%	"	255
Swedish	D.	Plain Carbon	0.90–0.95%	"	260
"	E.	M.N.O.M.	0.35–0.45%	"	340
"	F.	Chrome File	1.26%	"	364

Altogether 166 experiments were made on the six classes of material with chisels made of high-speed steel, the chisel in each case being changed immediately the point gave way. In actual work, the chisel could have been used for quite a long time after the point had broken off, but in order to obtain as exact a comparison as possible it was decided to reject the chisel each time its edge snapped.

It was found that a harder material required a chisel with a more obtuse angle than a soft one, this being principally due to the fact that in order to break off each chip it was necessary to alter the angle at which the chisel was held with the work, thus causing a side pressure on the point. This usually occurs at the end of a cut, when it becomes necessary to guide the chisel to the surface. For this reason, it was found advisable to make the actual cutting angle short, and to round off the remainder, in order to give greater strength and support to the point.

The most suitable angles found for the various classes of material were :—

A.	Plain Carbon	.	.	.	.	66°
B.	B.N. Chrome	.	.	.	.	67°
C.	Plain Carbon	.	.	.	.	72°
D.	Plain Carbon	.	.	.	.	73°
E.	M.N.O.M.	.	.	.	.	79°
F.	Chrome File	.	.	.	.	81°

(2) **Hardness.** The usual method of hardening high speed steel chisels is to heat up to 1200° C., and then either to cool off in an air blast or to quench in oil. Both these methods were tried with a series of variations of temperature from 1300° C. down to 750° C. Whether the chisels were cooled in air or oil was found to make little difference in the life of the chisels, but a hardening temperature of about 900° C. gave the best results. When lower temperatures were tried, the chisel edge was too soft, and showed a tendency to run over or wear away. On the other hand, the use of high temperatures caused the chisel edge to break away in flakes, and, if subsequently tempered, the chisel edge bent over after very little use.

From this series of tests the following temperatures were recommended for the respective qualities of billet.

A.	Carbon Steel	.	.	.	Air hardened at	900° C.
B.	B.N. Chrome	.	.	.	„ „	900° C.
C.	Carbon Steel	.	.	.	„ „	900° C.
D.	Carbon Steel	.	.	.	„ „	950° C.
E.	M.N.O.M.	.	.	.	Oil hardened at	800° C.
F.	Chrome File	.	.	.	„ „	900° C.

The comparisons between the results of the tests of the various angles and the various hardening temperatures were based on a factor derived from the multiplication of the length of time the chisel was in operation and the weight of the material removed.

Bench Height and Fatigue.—Test No. 1. The height of the bench for this experiment was made 27" from ground level, and the surface of the billet 31". It was found that the man could not chip more than two cuts 10 $\frac{3}{4}$ " in length from B.N. Chrome material without becoming fatigued; also the average working period was 2.41 minutes, against 6.07 minutes required for recovery. The man had to give up chipping before the end of the shift on account of excessive fatigue. Altogether eighteen

chisels were used, and it appeared that it was impossible to get sufficient force behind the hammer at the bench height, and in consequence the shanks of the chisels vibrated in the sockets, and undue wear on the chisel edge was experienced.

Result Test No. 1.

	Minutes.	Per cent.
Total chipping time	108.57	22.62
„ rest periods	273.43	56.97
Preparation	30.00	6.25
Lunch	28.00	5.83
Early finish	40.00	8.33
Total	480.00	100.00

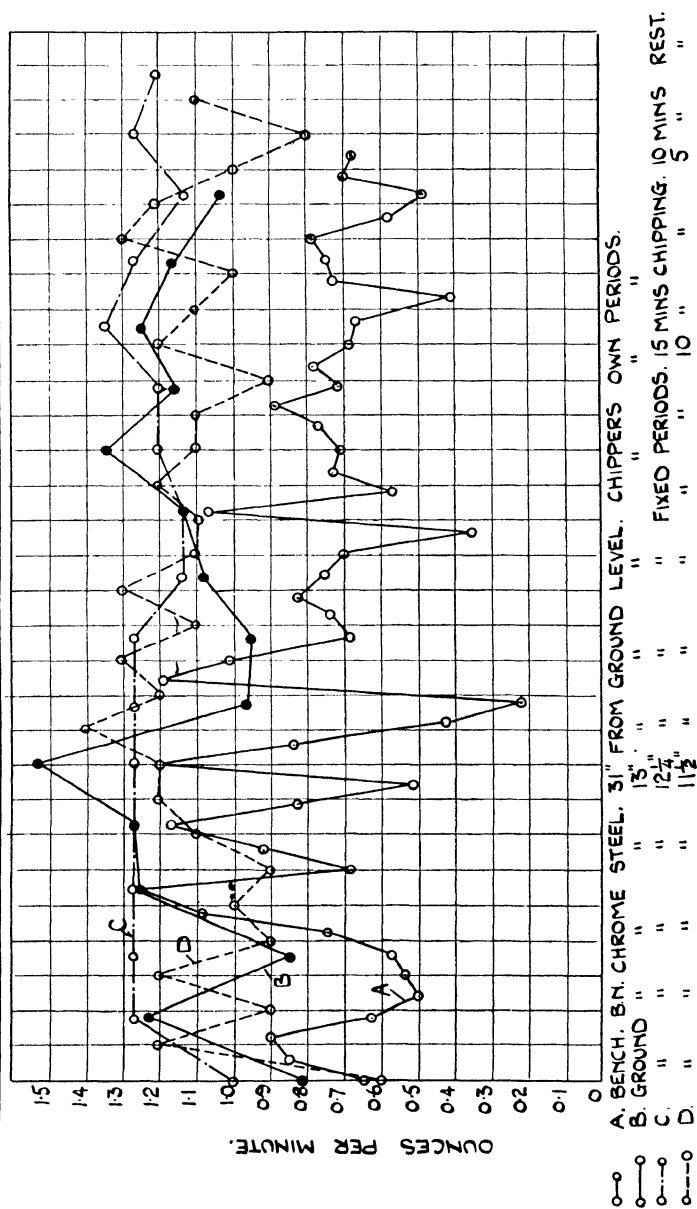
Total number of rest periods	45
„ „ „ grooves	96
„ „ length chipped	967½"
„ weight removed	5 lb. ½ oz.

Test No. 2. The second test was taken at a height of 13" from ground level, this being the height commonly accepted in the works, and the man was allowed to take his rest pauses when he felt they were necessary. This time it was found that the man could chip from 12 to 17 lengths of 10¾" before feeling any effect of fatigue. Five chisels were used during this test, the increase of the chipping rate was 51.35 per cent., and thus there was a considerable improvement on the result of the previous test.

Result Test No. 2.

	Minutes.	Per cent.
Total chipping time	236.85	49.34
„ rest periods	149.35	31.11
Fixing up at start	19.00	3.96
Lunch	25.80	5.38
Hammer repairs	15.00	3.13
Discussion	24.00	5.00
Packing tools away	10.00	2.08
Total	480.00	100.00

Total number of rest periods	15
„ „ „ grooves	226
„ „ length chipped	2215½"
„ weight removed	16 lb. 11 oz.



fluctuation in the chipping rate than on the previous day; the man also complained of excessive fatigue, and it appeared that he would be unable to keep up the work on this system day after day. Five chisels were used during the test.

It was very clearly established that a man does more work when he has definite work, and predetermined work and rest periods, than when he is left to his own devices. Rest is certainly necessary in this class of work, and it is far better to institute definite times for relaxation than to compel the man to act defensively by slowing up, but at the same time pretending to work at full speed.

The two tests Nos. 2 and 3 illustrate this point; in both cases the time worked and the rest periods are about the same. On test No. 2 the average working period was 15·79 minutes against 15 minutes, and the rest pauses 9·96 minutes against 10 minutes. The reason for the difference in output was that when the man was left to his own devices he started by taking working periods of 19 and 20 minutes. These periods were too long, and, eventually, he had to reduce them to 9 minutes. This meant that whilst he was fresh at the beginning of the day, he tired himself out, and later on found that he was unable to keep up the pace he had set himself.

The rest pauses and working periods taken during test No. 4 were found to be unsuitable, and the increased output was negligible compared with the increase of time worked.

It must be remembered that during the experiments the man did nothing but plane the billets, whereas in actual work there are usually a few grooves to chip in each billet, and so there is a change of work in handling, moving from one point to another; moreover this also involved lost time.

To apply the system of definite rest pauses to everyday practice it is necessary to have all the billets inspected and marked where they require chipping and set out ready for work. The man is then able to chip along a row of billets for 15 minutes, and to turn them over during the 10 minutes rest.

The Hammers.—Following these tests, it was decided to make some investigations as to the actual effectiveness of various types and makes of hammer under working conditions. Up to this time, hammers had been more or less taken for granted and purchased on the representations and reputations of the various

makers, with occasional examination of mechanical construction, air consumption and cost of maintenance, actual or anticipated. For this purpose several hammers all in new condition were selected for exhaustive test and comparison.

Preliminary Studies.—In order that the results of the comparative tests should be capable of evaluation some preliminary information was collected. For example, time studies were made of thirty men, to determine how much of the shift time was spent in chipping with the following average division of shift time.

Chipping	360 mins.
Grinding chisels	12 "
Setting out work	20 "
Replacing work	8 "
Delays	60 "
Meals	20 "
Total	<hr/> 480 " <hr/>

Next, in order to arrive at the proportion in which steels of differing hardnesses were treated, they were divided into three grades, and statistics as to the quantities of these grades treated per 24 hours were got out over a long period. The grades were 0·10 per cent. carbon or soft, 0·43 per cent. carbon or medium hard and 0·82 per cent. carbon or hard. The average quantities treated were :—

Grade.	Tons per 24 hrs.
0·10% C	30
0·43% C	99·5
0·82% C	42·5

giving a total output of 172 tons per 24 hours.

The average number of men required to give this output was 116, of whom 102 were shift workers, working from 6 a.m. to 2 p.m., or 2 p.m. to 10 p.m., or 10 p.m. to 6 a.m. The remaining 14 worked the ordinary day shift.

From cost figures, it was found that the total cost per man per hour was 2s. 8·12*d.*, of which compressed air cost 2·7*d.* only. This indicated that test results should be stated as weight of material removed per minute, and although the compressed-air consumption was measured by means of an air flow meter, and the material removed per cubic foot of air was calculated, this was ignored.

Hammers were tested on these three groups of steel, the same workman being studied in each test in order that the comparison might hold. The chippings from each batch of billets were collected and carefully weighed, and the actual chipping time was measured by means of a stop watch.

A new hammer of the type in general use in the shops at the time, *A* below, was selected for comparison with the other hammers, and the output rates on the three classes of steel were as follows :—

Steel.	Hammer.	Material removed.	
10% Carbon	<i>A</i>	1.73	ozs. per minute
	<i>B</i>	3.04	„ „
	<i>C</i>	1.63	„ „
	<i>D</i>	1.48	„ „
	<i>E</i>	2.91	„ „
	<i>F</i>	2.94	„ „
0.43% Carbon	<i>A</i>	1.90	„ „
	<i>B</i>	2.71	„ „
	<i>C</i>	1.18	„ „
	<i>D</i>	1.54	„ „
	<i>E</i>	2.49	„ „
	<i>F</i>	2.41	„ „
0.82% Carbon	<i>A</i>	1.45	„ „
	<i>B</i>	1.66	„ „
	<i>C</i>	1.05	„ „
	<i>D</i>	1.71	„ „
	<i>E</i>	1.51	„ „
	<i>F</i>	2.15	„ „

Evaluation of Results (Fig. 54).—In order to discover what would be the result on the number of men employed to do the same work, of changing from the hammer in use (*A*) to the hammers shown to be the most effective by these tests, it was necessary first to find by calculation the manner in which the men, 116 in number, were distributed over the three classes of steel. This calculation is shown below.

The number of men engaged on any class of steel per 24 hours varies directly as the tonnage chipped in that class, and inversely as the hammer rate on the same class.

Thus the numbers of men on the classes of steel are in the proportions of $\frac{30}{1.73}$, $\frac{99.5}{1.90}$ and $\frac{42.5}{1.43}$, or of 17.3, 52.3 and 29.3.

The total number of men engaged is 116, and dividing this

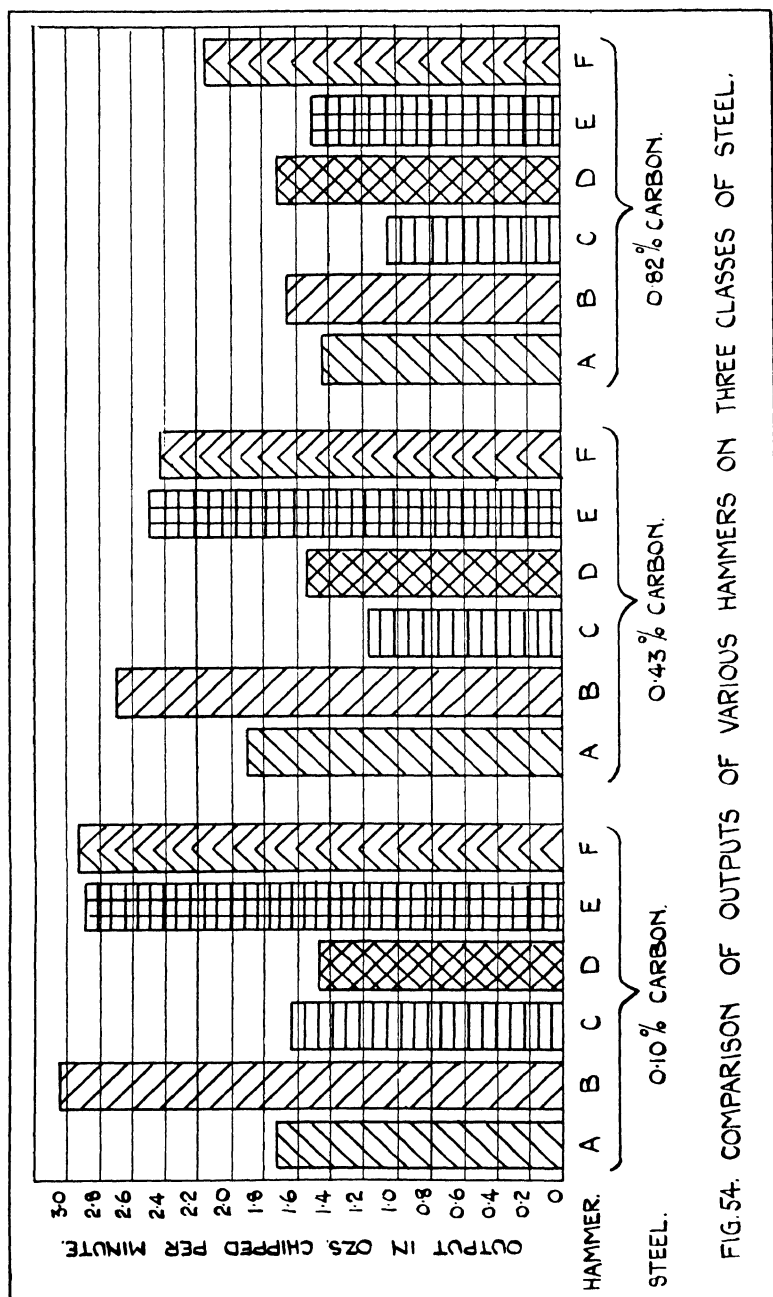


FIG. 54. COMPARISON OF OUTPUTS OF VARIOUS HAMMERS ON THREE CLASSES OF STEEL.

number in these proportions, we get the number of men engaged on the different steels :—

On Soft Steel,	$\frac{17.3}{98.3} \times 116 = 20$ men
On Medium Steel,	$\frac{52.3}{98.9} \times 116 = 62$ men
On Hard Steel,	$\frac{29.3}{98.9} \times 116 = 23$ men
Total = 116 men	

It was found in the tests that hammer *F*, which gave the best rate on hard steel, jarred the hand, arm and shoulder of the man holding it when chipping this class of steel, and caused excessive fatigue. This hammer was therefore rejected, and hammer *D*, the next best in this class, was selected for hard steel, and *B*, the best in the other two classes, was selected for soft and medium steel. The number of men required to give the required output of each class was then calculated.

Low Carbon Steel.—With *A* hammer, 20 men were employed. Assuming that *B* hammer was substituted, the amount of material removed would be increased from 1.73 ozs. per minute to 3.04 ozs. per minute, and the time occupied in doing the same amount of work would be reduced from 360 minutes to $\frac{1.73}{3.04} \times 360 = 204$ minutes.

The analysis of the shift time for the same amount of work would then be :—

Chipping	.	.	.	.	204 mins.
Delays	.	.	.	.	60 „
Other work	.	.	.	.	40 „
Meals	.	.	.	.	20 „
Total	.	.	.	.	<u>324 „</u>

Thus the time saved per man per shift is

$$480 - 324 = 156 \text{ minutes,}$$

and the reduction in the number of men engaged a full shift to do the same work is

$$\frac{156}{480} \times 20 = 6.5, \text{ say 6 men.}$$

Medium Carbon Steel.—With hammer *A*, 62 men were employed, and on this material *B* hammer removed 2.71 ozs. per minute, as against *A* 1.9 ozs. per minute.

As before, the new chipping time is :—

$$\frac{1.9}{2.71} \times 360 = 252 \text{ minutes,}$$

and the shift for the same work would become

Chipping	.	.	.	.	252 mins.
Delays	.	.	.	.	60 „
Other work	.	.	.	.	40 „
Meals	.	.	.	.	20 „
Total					<hr/> 372 „ <hr/>

and the time saved per man per shift is

$$480 - 372 = 108 \text{ minutes.}$$

The reduction in men for a full shift and the same work is

$$\frac{108}{480} \times 62 = 13.9 \text{ men, say 13.}$$

High Carbon Steel.—With the hammer in use, 34 men were employed, and on this material hammer *D* removed 1.71 ozs. per minute as against *A*'s 1.45 ozs. per minute.

The chipping time per man was :—

$$\frac{1.45}{1.71} \times 360 = 305 \text{ minutes,}$$

and the shift for the same work would become

Chipping	.	.	.	.	305 mins.
Delays	.	.	.	.	60 „
Other work	.	.	.	.	40 „
Meals	.	.	.	.	20 „
Total					<hr/> 425 „ <hr/>

The time saved per man per shift was

$$480 - 425 \text{ minutes} = 55 \text{ minutes,}$$

and the reduction in the number of men on full shift was

$$\frac{55}{480} \times 34 = 3.8, \text{ say 3 men,}$$

So that, assuming the most effective hammer in each class of steel was used, the work could be done with $6 + 13 + 3 = 22$ less men, or 94 instead of 116, giving a reduction in labour and maintenance of hammers of 19 per cent. Actually, hammer *B*, the best all-round hammer, was selected as the standard, in order not to have two types of hammer in use in the same shop, and the change over was made gradually, new hammers of the selected type being purchased as those in use became ready for replacement.

In this way it was possible to measure the effectiveness of the proposed equipment and calculate the economic result of purchasing it. More frequently the selection is made as the result of someone's prejudices or opinions, or the salesman's statement that someone else has purchased, and so, unless the best equipment is offered by the best salesman, which may or may not be the case, progressive improvement is limited.

ROUGH TURNING OF ROUND BILLETS

IN the foregoing example the occurrence of blemishes on the surface of rectangular billets is referred to, and some explanation of their origin is given. In that case, the blemishes are removed by chipping them out individually before the billets are re-rolled into smaller sections.

The same blemishes occur on round billets which have also to undergo either further rolling or forging into tubes; in this case, either because the steel is of higher grade and made to higher standards, or, sometimes (for example in tube making), where the steel is very severely treated, it is the practice to rough turn the billets all over, and in order to permit of this they are produced (*i.e.* rolled) of a diameter about a quarter of an inch larger than the re-roller requires. A rough cut of $\frac{1}{8}$ " brings the billet or bar down to the required size, and at the same time removes all the surface flaws and blemishes.

In order that this process might be carried out as quickly and cheaply as possible, a special machine was designed and built. The machine consisted of a cutter head that would carry four or six cutters (according to the size of bar to be turned) which was made to rotate by a motor, through gearing, at speeds that could be varied. The cutters were so placed, and the feeds so arranged, that each one traced its own path on the bar. The cutting speed in feet per minute was the product of the number of revolutions (per minute) of the head, by the circumference of the bar in feet (the bar itself did not rotate).

The rate at which the bar could be fed through the head was four or six times the rate at which feed could have been applied if the bar had been in an ordinary lathe with a single tool of the same size and shape.

Mounted on the bed of the machine were two slides, one on each side of the head, that could be moved along it by a specially designed powerful drive, at rates that could be varied at will. This drive was engaged with the aid of compressed air.

Mounted on these slides were powerful vice grips also operated by compressed air. There were supporting rollers for the bars. When the machine had been set up for the size of bar to be turned, the cutting speed and feed decided upon, and the appropriate gears engaged, the method of operation was to feed the bar at the ingoing end of the machine, close the vice, and engage the feed, which pushed the bar through the head. When it had got sufficiently far through the head, the other vice took hold of it and pulled.

The machine was of very heavy and rigid construction and amply powered. It was guaranteed to be able to machine mild steel bars between 3" and 6" diameter, at the rate of 60" per minute, and this guarantee was fulfilled. It was not expected that this rate would be reached with the alloy and high carbon steels the machine was intended to turn, because these were much harder. The machines on which this work was previously done had a maximum feed of 5" per minute.

When this machine was put into service, the results achieved fell far below expectation, and the production engineer was put on to improve matters.

A preliminary time study showed that there was considerable waiting for material, the older machines being given preference. When this had been remedied the analysis of time was as follows :—

Working	77.7 per cent.
Changing tools	12.8 „
Other delays	9.5 „

The routine method of changing tools was improved, so that this time was reduced to 7.0 per cent., but it was thought that this loss of time should be almost completely eliminated; moreover, the consumption of tools was excessive, the feeds in use were considered to be too low even for the harder steels, and this suggested that the tools, which were made from 17 per cent. tungsten steel, were not good enough for the purpose. The tool form in use is shown in Fig. 55.

Before examining the possibility of better tools, the condition of the bars as received for turning was considered. They were tested for hardness and gauged for size. It was found that some were too hard, and not uniformly hard from end to end, and arrangements were made that resulted in improvement

in annealing. As for size, it was found that the rolling tolerances (plus or minus $\frac{1}{32}$ ") were not always adhered to, and some of the bars were not round. The machine operator was given a set of gauges, and told that any bars that did not comply with these gauges were to be set aside for special treatment (*i.e.* two cuts instead of one).

These interim measures produced an improvement that made conditions tolerable, thus giving time for a thorough examination of the tool question to be made. After some preliminary experiments, it was decided to try the effect of using tools tipped with tungsten carbide, but these were soon shown to be too brittle for the heavy cuts that were being taken. Then tools tipped with stellite were tried, and as these seemed promising, a new tool form taken from the standard sheets published in Germany (shown in Part I) was experimented with. A long series of experiments (it is not necessary to describe them here) was made, the several elements of the shape being progressively varied until the tool form shown in Fig. 55 was arrived at, and considered to be the most satisfactory over the whole range of materials that were being processed. Up to this time the tools had been judged by the number of bars (*i.e.*, length of material) that could be machined before the tools failed. As it was very undesirable that the tools should be allowed to fail at all, it was decided that they should be taken out and re-ground after 90 minutes work, and on this basis it was calculated that a ratio of cutting time to shift time of at least 80 per cent. could and should be maintained.

A table of cutting speeds, feeds and standard output per shift for each size and quality of bar machined was drawn up (Table 12). As this investigation had taken some time, and there had been many failures, it was considered necessary to stage a demonstration before putting the new routine and values into operation, especially as the purchase of some special plant for the making and reconditioning of the tools would be necessary.

It was therefore arranged that the new tools and new routine should be operated under supervision for a week on one of the three shifts, the old routine and the old tools being used on the other two.

The results of this demonstration are shown in Table 13,

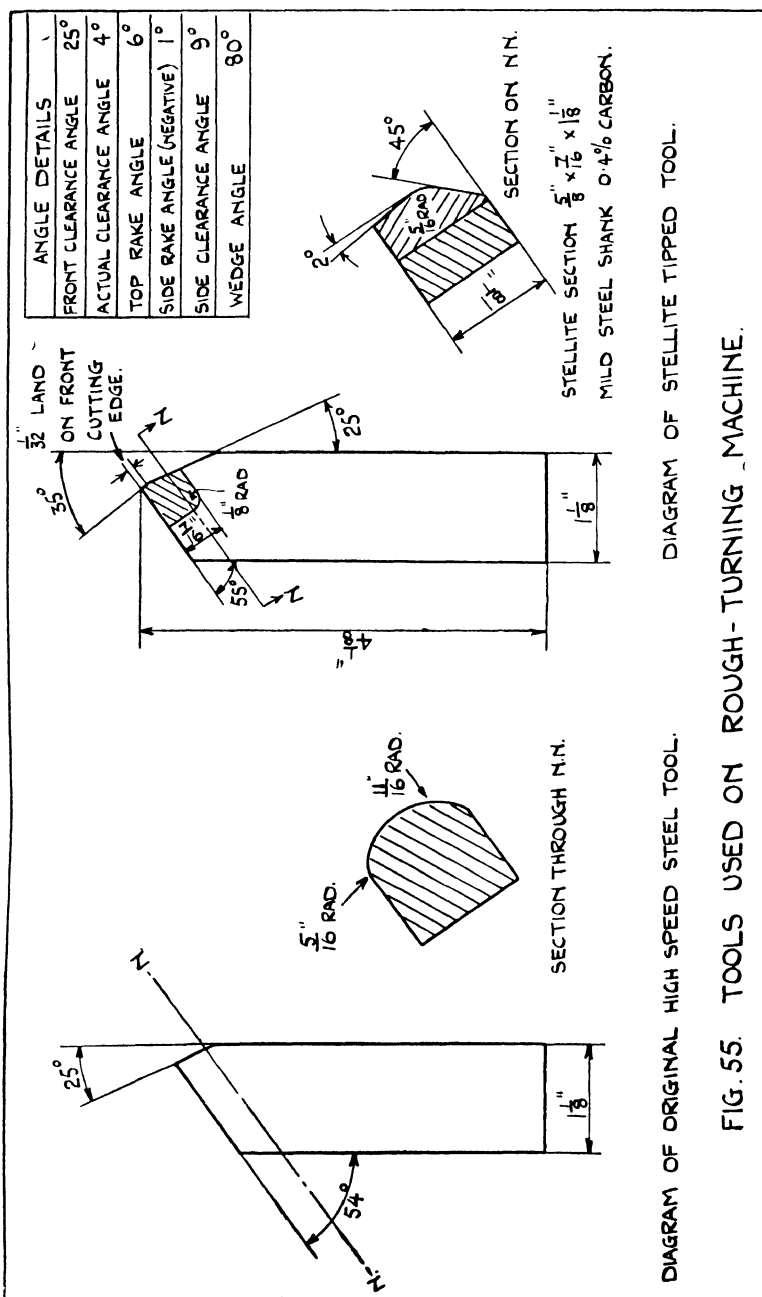


DIAGRAM OF ORIGINAL HIGH SPEED STEEL TOOL.

DIAGRAM OF STELLITE TIPPED TOOL.

FIG. 55. TOOLS USED ON ROUGH-TURNING MACHINE.

TABLE 12.

List of Cutting Speeds and Feeds.

Type of Steel.	Carbon, %.	Dia. of Bar in inches.	M/c Speed, revs./ min.	Feed, ins./ min.	Total, ft./ shift.	Piece- work Rate, pence/ ft.
Chrome (1.50%).	0.90/1.05	3½/3½	60	15.7	470	0.613
Chrome (0.50%).	0.35	3½/4½	60	30.5	915	0.314
Nickel Chrome Molybdenum.	0.16	4 and under	60	22.7	680	0.424
” ”	0.16	Over 4	46	15.7	470	0.613
Chrome Molybdenum.	0.45	4 and under	60	22.7	680	0.424
” ”	0.45	Over 4	46	15.7	470	0.613
Nickel Chrome.	0.43	4½/5	46	15.7	470	0.613
Chrome Vanadium.	0.50	3¾ and under	60	30.5	915	0.314
” ”	0.50	Over 3¾	60	22.7	680	0.424
Nickel.		3¼/4½	60	22.7	680	0.424
Silicon Chrome.	0.50	3¾	60	15.7	470	0.613
Mild Steel.	0.82	3¼	60	30.5	915	0.314
Nickel Chrome.	0.30	over 4	60	22.7	680	0.424

TABLE 13.

Result of Demonstration of Tools.

Morning Shift. Using Stellite Tools.				Afternoon Shift. Using High-Speed Tools.			Night Shift. Using High-Speed Tools.		
Day.	Ft. Ma- chined.	Tons.	M/c Time. min.	Ft. Ma- chined.	Tons.	M/c Time, min.	Ft. Ma- chined.	Tons.	M/c Time, min.
Monday	581	8.4	304	243	4.0	375	262	5.4	344
Tuesday	332	5.5	160	477	9.0	295	476	10.0	300
Wednesday	448	4.8	345	170	3.6	265	214	2.9	260
Thursday	402	4.3	326	240	3.1	258	252	3.8	332
Friday	343	9.8	273	319	3.5	421	248	2.6	374
Monday	461	5.1	320	503	9.0	310	468	2.8	320
Total	2567	37.9	1728	1952	32.2	1924	1920	27.5	1930

Ft. Machined 2567
 Per Minute 1728 = 1.485.

1952 + 1920 = 3872
 1924 + 1930 = 3854 = 1.00.

I.e., increase of efficiency, 48.5%.

and indicate that the new tools gave roughly a 50 per cent. increase of output over the old ones.

The table for speeds and feeds had been deliberately fixed at very safe values because it was desired to avoid, for some time, any risk of tool failure. But it is known that as soon as the new method is fully accepted by everybody, the feeds can be increased. It should be stated that the finish of the bars turned on the new method was very much better than those turned on the old.

INDUSTRIAL PSYCHOLOGY IN A CIGARETTE FACTORY

It is not often that a description of the application of psychological methods in a factory is published, and it is still more rare for figures to be given as to the results. Such a study was made by Dr. Karl Wirth in a cigarette factory, and published by him in booklet form in German.

The following, extracted from a translation of the booklet, reviews the general characteristics of the factory, the analysis of the work, the working conditions, the work itself, and indicates the qualities necessary in the workers. It describes the methods of management and the wages system before rationalisation took place, and the consumption of material. The time studies are also briefly described; so, too, is the selection, testing and training of workers, with particulars of supplementary and practical instruction. Finally, comparison is drawn between the work done in the two periods, before and after rationalisation.

(A) CHARACTERISTICS OF THE FACTORY

(1) **General.**—The factory was specially suited for the purposes of such a treatment, because

- (a) It employed a large total number of workers.
- (b) A large number of workers trained to the same kind of work were required.
- (c) The length of time available for the training of the individual workers was strictly limited.

The manufacture of cigarettes by machinery in this factory was abandoned, and hand making was substituted for social reasons—namely, to increase the number of people employed, and so relieve unemployment. This change from machine to hand work resulted unsuccessfully from an economic point of view, but this does not diminish the interest in the work

done, or in the results or the light thrown on the methods, since we are not here concerned in comparing machine with hand work.

Because hand work was the predominating feature in the factory, it was realised that the economic success achieved would depend almost entirely on the collective results of the performances of the individual workers, and that, therefore, the systematic and methodical training of the workers was of paramount importance. Psychological studies of the work itself, rationalisation of the methods principally from the psychological view-point, as well as the training of the workers were clearly called for.

(2) **Analysis of the Work.**—Since the factory was started some time before it was decided to use these methods, it was possible to make a comparison between the decisive factors before psychological rationalisation and after, and the success or failure of the methods could be ascertained more easily, and with greater certainty than is usually the case.

A production plan divided into products, production groups and jobs, and a working plan with processes, operations, motions and units of motions were developed; a relatively simple matter because of the single product, cigarettes. These considerations do not show any new ideas in comparison with such plans as are given in Part I, chapter 3, and, therefore, it does not seem worth while to show the scheme of the production and working plans; but it may be noted that this analysis of work, originally developed for the very complicated products of the metal-working industry, was easily adapted and extremely useful in quite a different industry, of which nobody had thought when designing it.

It was apparent that the workers, mostly women, could be divided into the following categories:—

- (1) Cigarette makers.
- (2) Cigarette cutters.
- (3) Cigarette packers.
- (4) Workers on card box manufacture.
- (5) Auxiliary workers, for instance, on material preparation.
- (6) Teacher.
- (7) General workers such as those for transport, fitters, etc.

The first category is naturally the largest in number, and the most important. Economic success depended almost entirely on the work of this group. Moreover, as the experience of the investigation has shown, the results arrived at from this class of worker may be applied also to the other classes of workers. For this reason only the first group is dealt with in the following analysis.

It was necessary first of all to give an accurate description of the work and the manner in which it was to be done, in order that the methods and system of selecting and training workers best adapted naturally to the work could be laid down.

(3) Working Conditions.—The workrooms in the factory had the character of friendly sitting-rooms, not offering exaggerated comfort, but bright and cheerful, sufficiently heated in winter time, and well ventilated. Changing-rooms, lavatories, etc., were adequately provided. Work clothes, white frocks with short sleeves and white caps, were provided by the works and washed every week, an important factor in view of the material which the women had to handle. The working time was comparatively short—42·5 hours per week—and sufficient stoppages were permitted. The workrooms were not overcrowded, and care was taken that every worker had a good light, a comfortable chair, and a rest for the feet. The work itself was light handwork, but, notwithstanding this, nothing was neglected which would make the work as easy as possible. The tools especially, which were very simple pieces of wood and thick vellum, were the result of careful study and thought.

(4) The Work Itself.—The work consisted in forming a loose mass of tobacco shreds to approximately the shape it has in the cigarette by rolling it in a sheet of parchment, and afterwards pressing the shaped tobacco by means of a wooden rammer out of the parchment into a shell of cigarette paper, of which a pile stood in a handy position by the side of each worker. The empty shells had been purchased ready made. The cigarettes in this stage were put into paper boxes, which were numbered according to the number of the worker and her workplace. Slips of paper of suitable size, prepared and delivered to the workers in sufficient quantities, were put between the rows of cigarettes. (The packing of the cigarette boxes was not the duty of this class of workers.) The individual operation

and motions and their sequence had been studied carefully, because it was found that there had been great differences in the manner in which this apparently simple work was performed. The most favourable way was shown to be by these motions :—

- (a) Preparing the tobacco.
- (b) Rolling the tobacco in the parchment.
- (c) Picking up the shell.
- (d) Pushing out the tobacco into the shell.
- (e) Taking off and laying aside the cigarette.
- (f) Cleaning the work place.

As auxiliary motions may be mentioned :—

- (1) Taking out useless parchments, folding and putting in new ones.
- (2) Cleaning the rammer, if adhesive, with glass paper.
- (3) Fetching shells and tobacco.
- (4) Renewing the stock of shells on the workplace.
- (5) Renewing the stock of tobacco on the workplace.

So much about the work itself. It may be added that the investigation went deeply into all the details of the work, using all the modern auxiliaries available, especially photography. When necessary—for more complicated motions—moving pictures were taken, or photographs of small electric lamps connected with the hands of the worker, which give light lines on the moving picture. These were examined on the screen to see whether any simplification of the movements were possible.

(5) Necessary Qualities of the Workers.—The workers had come from different branches of industry, though naturally the majority, perhaps 60 per cent., had already been in the cigarette trade. As it did not seem advisable or necessary to limit the choice of workers to those who had already had experience, since they were going to be trained, this was not made a condition of engagement. The age of the workers varied from under 18 to over 30, but less than 15 per cent. exceeded the upper limit, and only a few of those under the lower were chosen, because experience with young workers was not encouraging. Before the investigation described, special

measures of selection had not been used in the engagement of the workers; but care had been taken that their hands should not be too large nor rendered unsuitable by earlier work.

After investigation of the work, and observation had been made of all other circumstances, it was established that workers with the following qualities should be selected :—

- (1) High degree of skill with the fingers.
- (2) Good simultaneous work with both hands.
- (3) Desire to take pains.
- (4) Sense of proportion and symmetry.
- (5) Constant impulse as far as possible, normal practical understanding, and average intelligence.

Later we shall see what methods and auxiliaries are used in testing the workers for these qualities.

(B) BEFORE PSYCHOLOGICAL RATIONALISATION

(1) Former Methods of Management.—After drawing up the analysis of work as above, and laying down the methods and manner in which it was to be carried out, an examination was made of the steps that had been taken previously to obtain a high standard of achievement, and it can be stated (says the publication) that the methods adopted showed careful thought and good management. This enhances the importance of the fact that the scientific methods afterwards adopted achieved considerable success in what was, already, a relatively well organised and managed factory, and indicates that they are worthy of careful consideration. Everybody knows that it is easy to show great progress and improvement where previously there has been a relatively low state of organisation. In a well-organised and managed factory one has to be content if one can obtain a much smaller improvement.

In this factory the management had taken what seemed to be a wise precaution in engaging a number of experienced workers, who had made cigarettes for many years in other factories. This measure, however, proved a mistake, inasmuch as each of the women had her own method of work, different from the others, and the majority had no real ability for teaching and training workers less experienced, or untrained.

Therefore, just what should have been avoided was introduced into the factory : different methods of procedure for the same work, with the result that the expected performance could not be attained. Fig. 56 shows what the average output of cigarettes should have been according to the expectations of the management, and what it really was.

(2) **The Wage System.**—The investigation of wages had the following results : Before any agreements had been reached, rates of 5·6*d.* per hour were paid for workers under 20 years, and 5·7*d.* per hour for workers over 20 years of age. Later on there was an increase to 6·4*d.* for every worker who reached an hourly output of 235 cigarettes. The result was that in the first week after the increase 20 per cent., in the second 29 per cent., and in the third 29·5 per cent. of the workers reached this output. Then a more detailed agreement was made : the hourly rates were fixed at 5·7*d.* for daily output up to 1799 cigarettes per shift, or 211 per hour at 8½ hours per day ; 6·1*d.* per hour for a daily output of from 1800 to 1999 pieces, or 211 to 235 per hour ; 6·5*d.* for a daily output of 2000 pieces and more, or over 235 per hour. This agreement had the result—which anybody with experience on the question of wages would have predicted—that the output of the two higher groups was very near—that is, only just above—the two limits 2000 and 1800, and for the third group—probably according to tacit agreement between the workers—to a maximum of 1500 pieces. In the first week after the agreement

65·9% of the workers earned 5·7*d.* per hour.

12·2% „ „ „ 6·1*d.* per hour.

21·9% „ „ „ 6·5*d.* per hour.

This ratio changed slowly and steadily, and in the fourth week after fixing the agreement

47·0% of the workers earned 5·7*d.* per hour.

27·5% „ „ „ 6·1*d.* per hour.

25·5% „ „ „ 6·5*d.* per hour.

The management of the factory had expected that the real cost of wages according to this scale of payment would be 0·0276*d.*, 0·029*d.*, and 0·032*d.* per piece respectively, and the average of the whole would be between these limits, and come

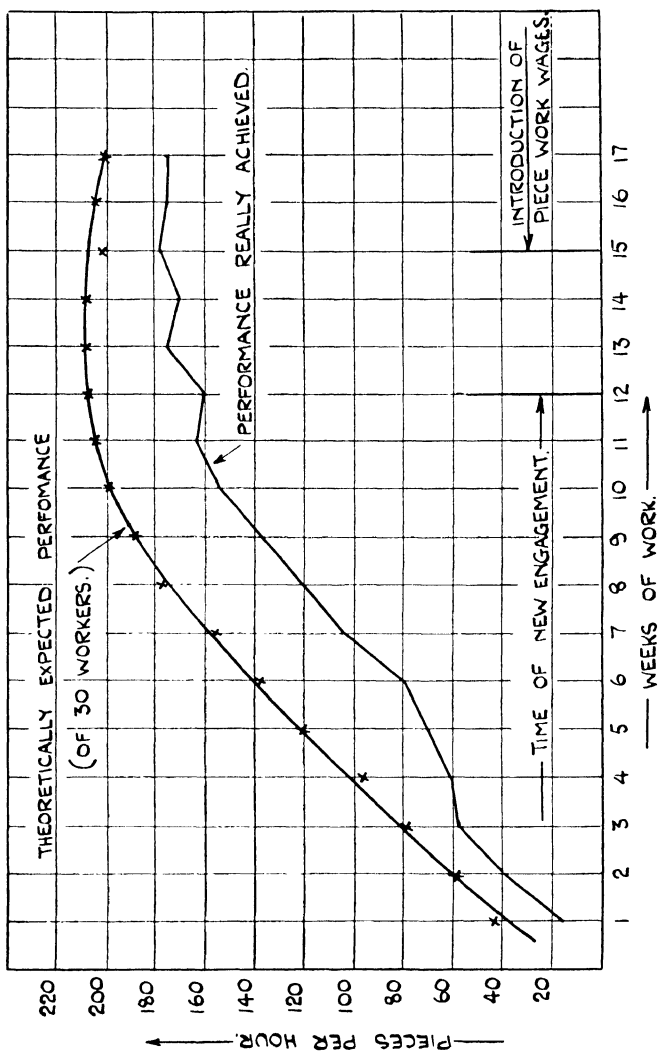


FIG. 56. COMPARISON BETWEEN EXPECTED AND ACHIEVED PERFORMANCE.

down according to the increase in number of the group with higher and the decrease in the number of the group with lower wages. Surprisingly, this was not the case. In the whole period in question the costs of wages per piece—as a careful investigation showed—never fell below 0.032*d*. There may be a series of causes for this fact; but we will not discuss them. Certainly, there was a lack of organisation, and this explained why the expectation, under which the agreement with the workers was made, was not realised. This was not the least of the causes why the economic achievement of the factory was not great enough, in spite of the endeavours of all interested.

(3) The Amount of Material Used.—It is further necessary to consider the consumption of raw material during the period of training by the factory management. This is especially important, since the value of tobacco is very high, and is increased by customs duties and taxation. The loss of tobacco can be seen from the statistics given by the factory management, if we use the equation :—

Supply of tobacco to the production = weight of tobacco in the cigarettes after they are ready for despatch, determined as 38.2 ozs. for 1000 cigarettes + return of tobacco from production to store + loss of tobacco.

It was found that in four months 52,896 lb. were sent in to the production; the cigarettes made contained a quantity of 43,840 lb.; 7450 lb. were returned to store, and 1606 lb. could not be accounted for. The entire 7450 lb. returned, however, could not be used for production, being partly cut too short, partly not clean enough, and so 80 per cent. had to be destroyed. Therefore, the total waste in this period was :

$$0.8 \times 7450 + 1606 = 7566 \text{ or } 14.3 \text{ per cent.}$$

of the supply to the factory—an astonishingly high figure.

This was the condition of the undertaking when a trained investigator was called in to help to improve the economic circumstances.

(C) THE RATIONALISATION

(1) Time Studies.—To gain an objective measure—as far as possible—of the performance that could be attained, a series of time studies, with recording instruments, was

made. It will not be necessary to describe in detail how that is done, it need only be mentioned that some of the motions enumerated above were grouped and not measured separately, because some of them take merely a few hundredths of a minute. In addition, the following auxiliary work and sources of loss were observed and the times determined :—

- (a) Laying aside the cigarettes in wooden frames.
- (b) Counting the cigarettes in the rows if necessary.
- (c) Counting the rows.
- (d) Putting paper between the rows.
- (e) Trouble caused by bad shells.
- (f) Filling up the store of shells.
- (g) Filling up the store of tobacco.
- (h) Cleaning the hands and the work-place.
- (i) Conversation with fellow workers.

As may be seen, this investigation was made even more in detail than suggested before, and the work was facilitated by the use of the recording instruments. A special research was made as to the method of forming a fair average, and all the methods recommended in previously published literature on the subject were tried. Without going into this research in detail, it is only necessary to mention that the result was a decision to use, even in this pure hand work in mass production, the usual simple average method, in spite of declarations so often made that in this case the method would not be accurate enough. The result from the time studies may be seen from the following table :—

Worker number.	In work, weeks.	Percent- age of rejects.	Piece time without lost time, minutes.	Allowed working time, minutes.	Daily performance.		Increase in %.
					Before time study.	After time study.	
(1)	19	9.4	0.261	0.287	1450	1780	22.5
(2)	19	5.0	0.229	0.252	1800	2025	12.5
(3)	20	0.0	0.226	0.249	1500	2050	36.0
(4)	16	5.5	0.217	0.239	2000	2140	7.0
(5)	19	4.5	0.211	0.232	1800	2200	22.0
(6)	20	1.3	0.204	0.225	1800	2270	26.0
(7)	18	0.0	0.190	0.210	2000	2440	22.0
(8)	17	1.1	0.186	0.205	2000	2490	25.0
(9)	20	0.5	0.168	0.185	2000	2760	38.0

It is very interesting to see how the individual differences, which were to a great extent eliminated by the earlier method of working and of paying wages, distinctly reappear as soon as a wage is introduced that is based on sound and equitable principles, and an accurate fixing of standards is adopted. It may not be superfluous to repeat and emphasise that this desirable result can be obtained only if these methods are applied in the manner and spirit indicated in the first part of this book.

Now it is necessary to examine closely the methods of psychological vocational tests, training, and supplementary and practical instruction procedure as they were used in the factory in question.

(2) Selection and Testing of Workers.—First we may examine the principles on which are based the vocational tests used in the selection and grading of workers. The problem is to select from a number of candidates those who have the natural qualities that will enable them, when trained, to carry out a certain vocation.

It must also be determined whether certain natural qualities that were specified as necessary for the purpose are in fact necessary; or whether different qualities possessed by those shown to be good workers by other tests are those that should be sought.

If the matter is considered in the broader way suggested above, it will be recognised that it is not the aptitude for a single feature of the work that is decisive, but the average aptitude for the work as a whole; and it is evident that brief tests, however varied, are not in themselves sufficient, but that longer examination of the behaviour of the operatives, and of their work under normal conditions, is necessary in order to estimate the average attitude. Experience has shown that subjects tested show great differences in their capacities during short tests, and during the continuous work afterwards in the shops; some work quicker and better, and some slower and not so well, under the latter conditions. The methods of testing are therefore selected according to the following requirements.

(a) In order to obtain a particular type of worker, the subjects are to be examined, not with regard to a single quality, but much more generally.

(b) Tests are to be made in addition over an extended period, and the results evaluated on the basis of units of work done per unit of time, and the percentage of the work that reaches a prescribed standard of quality.

(c) The result is not to be stated in the form of good or bad marks for particular qualities, but as a critical description of manner and behaviour towards the different parts of the work, and as indicating how the subject may be classified as to type. The objective results of measurement of time, quantity and quality of product should be used only as auxiliaries, and not regarded as independent data.

On these principles the previously mentioned qualities were tested by simple arrangements; for instance, the skilfulness of the finger is tested by plaiting or twisting webs of paper into slitted cardboards; carefulness is tested by drawing a line between two curves with a distance of about 0.08" between them without touching the two curves with the pencil; practical understanding and intelligence are tested by simple arithmetical problems using the four rules, and by writing a curriculum vitæ, etc.

The great differences in capacity and performance may be illustrated by Fig. 57, which shows the average response of each of the first nineteen examinees to the tests for carefulness with both hands and plaiting work. It should be stated that these tests were made on persons who had already worked some time in the factory, and so had reached a certain degree of similarity.

It is especially necessary to see that the criticism of, and the impression given by, the person tested at the examination and the numerical results of the tests agree with the criticism made by the foreman who had supervised the work of the person in question, and with the development of capacity for becoming familiar with the new conditions of work. If there is a sufficient coincidence, it may be taken that the criticism is a fair one and, since every criticism of one human being by another is naturally subjective, and not absolutely faultless, this possibility to test one's own opinion about a subordinate should always meet with approval.

In this cigarette factory, this matter was very carefully dealt with. It would lead us too far were we to give a detailed

description of the whole procedure, but the record of the summary criticism of a single worker, the best of all tested, is given as an example.

Age 26 years; 6 years elementary school, 2 years evening school for handcraft apprentices; occupation as a worker—hairdresser, labourer and programme-seller in cinema; occupied in the factory as worker manufacturing cigarettes, about seventeen weeks.

(a) Psychological criticism: quick worker with good skilfulness of the fingers, in spite of loss of the first joint of the forefinger by accident; gifted for careful work as long as the tempo is not exaggerated. Simultaneous working with both hands is good, intelligence good, carefulness nearly good.

(b) Numerical criticism according to tests: plaiting work, time 0.91 minute—quick; simultaneously working with both hands, 2.85 minutes—very quick; faults 4—very accurate.

(c) Criticism of the foreman: in every respect very good; steady and quiet at work; sympathetic in relation to fellow-workers and superiors.

(d) Development of performances: The performance at the beginning of the work is not known. The worker shows a good average capacity after seven weeks, and attains by steady improvement after the thirteenth week to the highest performance, and this is retained without fluctuation.

It could be established by quoting further examples of such coincidence of the different criticisms that the described method of selection was well adapted to the practical requirements.

(3) Training of Workers.—Training is the second step towards obtaining workers of high quality. Training means, in the sense it is used here, teaching not only a certain dexterity, but also the application of this dexterity, so as to reach and retain without strain the required optimum performance. This should be done at the lowest possible cost, and in the shortest possible time.

Different methods of training can be distinguished:—

1. The spontaneous self-training. The worker tries to work with a tool by instinct.

2. The copying of an example. The worker watches how

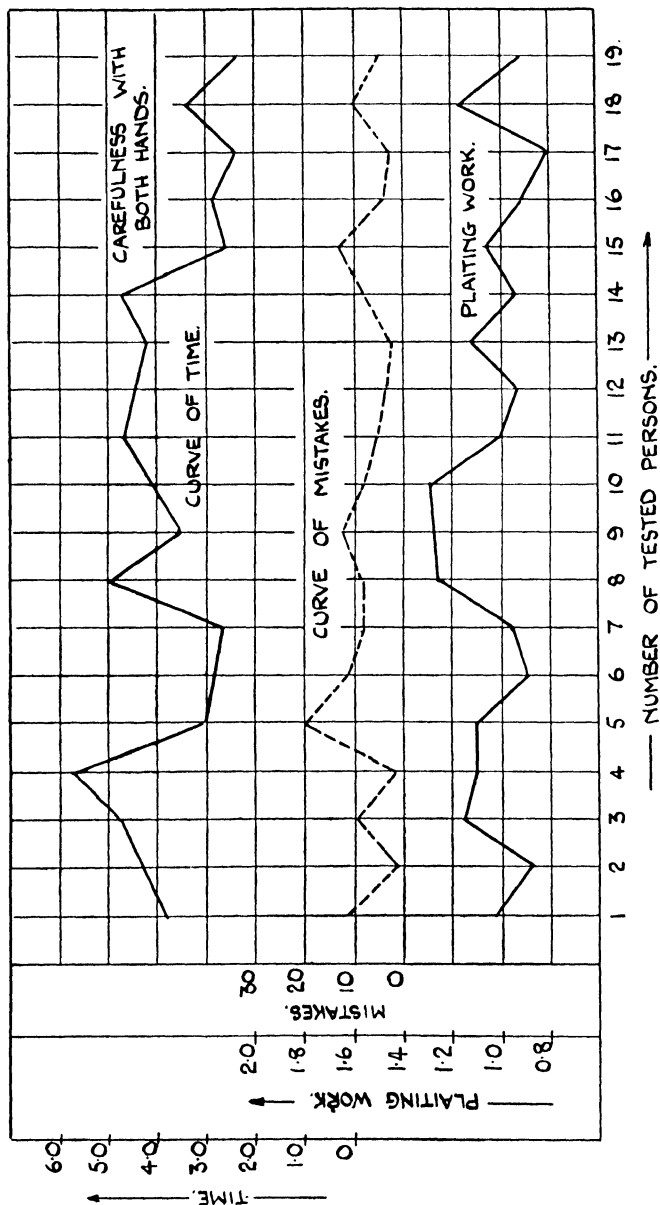


FIG. 57 NUMERICAL RESULT OF VOCATIONAL TESTS.

the different motions are made by another experienced worker and tries to copy them.

3. The usual professional training. The foreman shows the apprentice the motions necessary for the job.

This last method is by no means a bad one. This is shown by the enormous popularity which this method enjoys, and by the resistance shown by those interested to the so-called scientific methods of training, now to be referred to. This general method (3) is often almost sufficient, or is believed to be so, because better methods and the advantage gained by using them are unknown. These scientific methods are :—

4. The rationalised professional scientific method. It is based on time and motion studies and rationalisation of work. The best method found in this way is taught, but it is still a purely professional teaching without consciously using psychological principles.

5. The psycho-technic method uses the same ideas as method (4), but applies all the procedure of the modern science known as psycho-technique. In some measure it attempts to correct method (4) by the application of psychological principles.

6. The psychological method *starts* from these principles, and *at first* neglects the consideration of professional procedure, but of course takes the latter into account *later on*.

The combined ideas of the last three methods were used in the factory in question.

The practical carrying out of the training began with the selection of the workers to be trained. These were separated from the others, who had to continue working in the usual manner. First, instruction was given as to what results were expected from the training : (a) the production of cigarettes of the same quality according to weight, size, solidity, and density by all workers, (b) the production of a definite number of cigarettes in a unit of time, which would secure the economic success of the factory. Then followed an accurate explanation of all tools and auxiliaries necessary for the work, and of the best arrangement of the work-place; description of the individual operations and motions, whereby the trainees could be taught to recognise and avoid faults.

The practical exercise of the different parts of the work were carried out according to the following points of view :—

(1) Taking the right quantity of material and dividing it in a suitable manner.

(2) Cleaning the work-place from scattered tobacco.

(3) Exercises in the motions with transition from one to the other without stoppage.

(4) Receiving material, at first in small quantities, perhaps 2·8 ozs., for producing a definite fixed number of cigarettes (50 out of 2·8 ozs.); after some days about three times the quantity; later on the quantity usual in the factory.

(5) Raising the capacity (*a*) by giving a suitable rhythm of work, not too quick, not too slow, for a certain time, short in the beginning and increasing to between 1 and 1½ hours, (*b*) by setting limits according to the capacity of the individual worker, (*c*) with assistance of time study recorder.

(6) Controlling measures (*a*) by weighing regularly, (*b*) by feeling the cigarettes for testing equal distribution of tobacco in the length.

An exact time-table was worked out for the duration and sequence of all these exercises.

A comparison of the performance of three trainees with each other, and with the expected and realised performances under the old methods, is given in Fig. 58, and clearly shows the superiority of these new methods over those usually practised in industrial establishments.

Only one other detail need be mentioned : the loss or wastage of material during the period of training was reduced to negligible proportions; the total loss per worker during this time was 1·75 ozs.

(4) Supplementary and Practical Instructions.—Supplementary and practical instruction procedure should be used to maintain, and, if possible, even to raise the capacity for work of the trained worker. It is not necessary to say much about this matter, because the methods used are nearly the same as those described for training, except that some points, such as acquirement of speed and constancy of performance, are observed more than in the training at the beginning of the work. Since experience with this supplementary practical instruction

during later normal occupation in a factory is very seldom published, and the procedure itself is not often mentioned, it may be of interest to say that excellent results have also been obtained in other cases, for example in large textile works.

(D) SUMMARY AND COMPARISONS

The results obtained and the lessons to be learned from the experience gained in this factory may be summarised as follows :—

(1) **General.**—The question whether an improvement in the work and in the result of the work can be obtained by the application of the methods of psychological rationalisation must be answered decisively in the affirmative. It is often difficult to state numerically the value of the result. That is true, for instance, where we have to deal with a diminution of the danger of accidents, or with an improvement of the health of the workers, questions which could not be dealt with in this case because of the nature of the work in a cigarette factory. It is also difficult to give an objective decision whether the willingness to work is raised. It is certain, however, that the standard of performance has been raised by training and supplementary practical instruction, in spite of the lack of special impetus by an incentive wage system. The humour of the workers during the investigations was good, and it can be concluded therefore that the workers liked the methods adopted, and did not feel over-trained in any way. The workers throughout gave the impression that they were satisfied with their work. If it were possible to let them share the economic success of the methods, there is no doubt that this willingness for work would be permanent.

(2) **Comparative Figures.**—If the letter A signifies the results of the usual methods of management, and B the results of the application of the methods of psychological rationalisation, the comparison is as follows :—

- (1). A. Success of the training could be observed in only 20 to 25% of the workers.
B. After selection through vocational tests, almost every worker can be trained with success.
- (2). A. The duration of the training up to a performance of 1700 cigarettes per day was 11 to 12 weeks.

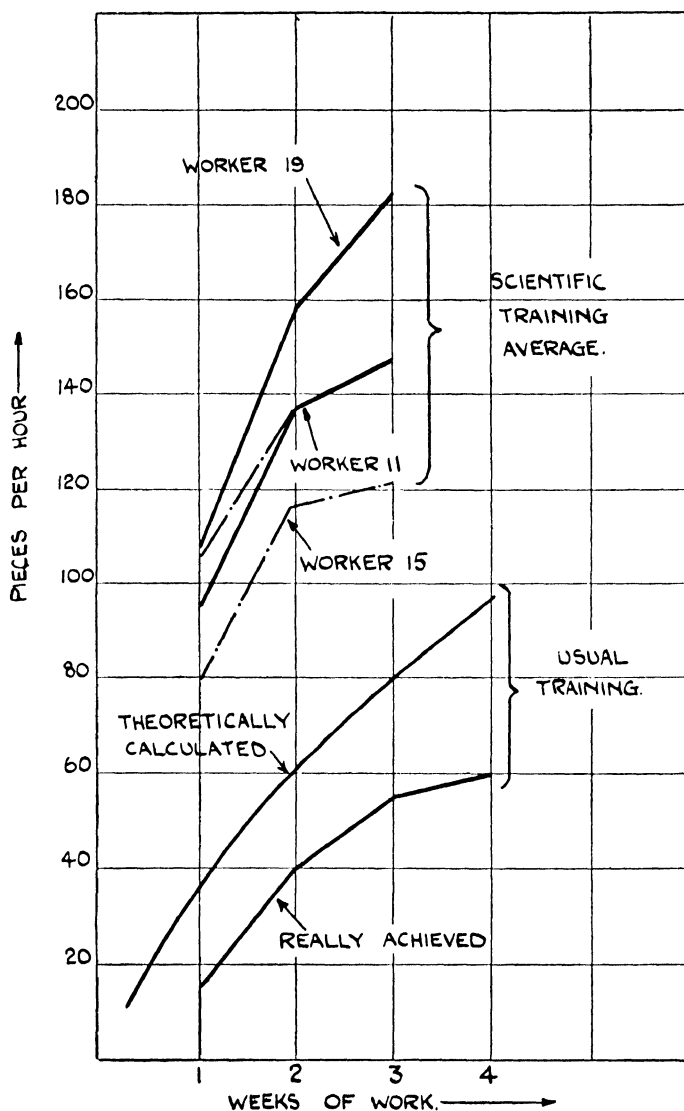


FIG 58. COMPARISON BETWEEN USUAL TRAINING AND SCIENTIFIC TRAINING.

- B. The same result can be obtained in 3 to 4 weeks, or a third of the former time.
- (3). A. Size and quality of the cigarettes during the period of training were often defective, and the cause of complaints from customers.
- B. The cigarettes delivered were good, and fit for consumption from the beginning of the training.
- (4). A. The avoidable loss of tobacco was 26·4 lb. per worker during the period of training.
- B. The loss of material was 1·75 ozs. per worker, *i.e.*, practically nil.
- (5). A. The average performance after a certain stabilisation was 175 cigarettes per hour from the thirteenth week of work.
- B. The performance could be raised about 20 to 30 per cent by supplementary instruction continuously. The highest performance was 300 cigarettes per hour.
- (6). A. The cost of wages for production of cigarettes after 13 weeks of work was 2s. 9½d. per 1000 cigarettes.
- B. If the same wages are paid, the costs are reduced to between 2s. and 1s. 9½d. per 1000 cigarettes.

(3) Comparison of Costs.—Finally we may try to make a comparison of costs, which, though not a true calculation, may yet give a good indication of the results which can be obtained.

(A) The period of training was 12 weeks, the average number of workers 215. The production during this time was 10,653,000 cigarettes and the amount paid in wages was £2557 13s. or 4s. 9½d. per 1000. Later on, during normal work, this wage cost could be lowered to 2s. 9½d. per 1000.

The loss of tobacco in 18 weeks, as we have seen, was 7566 lb.; therefore in 12 weeks at least $7566 \times \frac{1}{1\frac{2}{3}}$ or 5044 lb. If the customs and taxes are added to the value of the tobacco itself, this represents a loss of $5044 \times 3s. 7\frac{3}{4}d.$ or £920 or $\frac{18,400}{10,653}$ —that is, 1s. 8¾d. per 1000 cigarettes.

(B) The period of training was 3 to 4 weeks, and the average production during the time 138 cigarettes per worker per hour. If the same number of workers—215—is assumed,

they would produce, in the period of training, 4,750,000 cigarettes. The cost of wages, including the cost for the selecting and for the teaching staff, was £1075, and therefore the cost per thousand cigarettes was £1075 divided by 4750 or 4s. 6½d. In the next 8 weeks 15,136,000 cigarettes would be produced, at a cost for wages and salary of teaching staff of £1955, that is $\frac{39100}{15136}$, or 2s. 7d. per 1000; or these costs in

both periods can be calculated as : $\frac{(4 \times 4/6\frac{1}{2}) + (8 \times 2/7)}{12} =$

3s. 2¾d. per 1000 cigarettes.

Later on, during normal work, these figures could be lowered to between 1s. 9½d. and 2s. per 1000 cigarettes.

As already mentioned, the loss of material is very small; as the calculation shows ⅓d. per 1000 cigarettes. Taking all these figures we come to the following comparison.

(A) Period of training : 12 weeks.

	s.	d.
Wages per 1000 cigarettes	4	9½
Loss of material per 1000 cigarettes	1	11
	6	8½
	100%	
Normal work.		
Wages per 1000 cigarettes	2	9½
	100%	

(B) Period of training and start of work in factory, together 12 weeks.

	s.	d.
Wages, etc., per 1000 cigarettes	3	2½
Loss of material per 1000 cigarettes		½
	3	3
	48·5%	
Normal work.		
Wages, etc., per 1000 cigarettes	1	9½ to 2s.
	About 70%	

It should not be necessary to comment on these figures.

One last remark, and the description of this interesting experiment may be concluded. The comment was made on the work of Dr. Wirth, and his statement of result and conclusions, that, after all, the factory from the profit point of view was a failure, and this was undoubtedly true. From this it was argued that his conclusions were unsound, and that the methods used were without value. This is a superficial argument, and leads to a result that is false.

The cause of the failure of the factory was the competition of hand work with machine work, and must have been, more or less, anticipated. It did not fail because of the methods used—this is obvious—but in spite of them.

The really important thing to note is the great difference between work under the old conditions and work under the new.

STEEL-MAKING—REORGANISATION OF EQUIPMENT

THIS example shows how the need to revise the equipment of an open-hearth melting shop, and the manner in which it could be done, was examined by the Works Manager assisted by a committee. The committee consisted of the Works Manager as chairman, the Melting-shop Manager, the Chief Engineer, and two Production Engineers; the Traffic Manager and the Cost Accountant were called into the discussions at appropriate times. In this way, everybody who might be expected to know anything about the work in hand, and be able to make any useful contribution to the solution of the various problems, had an opportunity to do so.

Previous Changes.—The equipment of the works in question had undergone several changes. Originally there had been a Bessemer plant working in conjunction with a rail mill and tyre and axle forge, and rails, tyres and axles had been its principal, but not its only, products. The Bessemer plant had been superseded by an open-hearth shop, which, becoming too small for the requirements, had been replaced by a larger one. This larger one had had its capacity increased several times, and at the time the investigation was made there were in it four furnaces of 65 to 70 tons per charge capacity, and one of 40 tons. Of these furnaces, two of the larger ones made acid steel, and the remainder basic.

The product of the works also had been changed completely a few years before the investigation, in accordance with a scheme of rationalisation. It now consisted of ingots, blooms and billets of the highest possible quality of plain carbon and alloy steels, made in relatively small quantity, and plain carbon and alloy steels, still of high quality, but made in larger quantities to sell at moderate and competitive prices. The melting-shop under discussion produced the latter of these products, and whilst the quality was to be the highest that the

process permitted, the cost of production was a very important factor, and it was necessary that this should be brought as low as possible without endangering in any way the quality. The difficulties of working the shop to full capacity which resulted from changes already made and which it was desired to reduce or eliminate, could be and were conveniently divided into three groups :—

(1) The first group of difficulties were in connection with the casting-shop or pit, where the liquid steel was “tapped” off from the furnaces into ladles lined with refractory material, and then cast into ingots. After a period of cooling the moulds were stripped from the ingots, and the latter were sent to the mill or the stockyard, according as they were to be rolled immediately or not. The moulds were set aside to cool for a time, and afterwards cleaned, examined, coated inside, and then set up again for further use. The problems in this shop were many and various, but they all arose from lack of room and shortage of crane capacity.

(2) The second group were connected with the operating stage, and referred to the supply of raw materials in the correct quantities and at the right times, and putting them into the furnaces.

The raw materials consisted of scrap steel and iron, and pig iron, and smaller quantities of alloys, all of which came to the stage in charging-boxes or pans. The greatest care was always taken to ensure that each furnace received the right material for each charge, without any possibility of the charges becoming mixed. There were also quantities of slag-making materials and other minerals, some of which were put into the furnaces with the principal constituents of the charge, and some at other times, during the working cycle.

(3) The third group of difficulties arose from the furnaces. These were in rather bad condition, and it was necessary to rebuild them completely. Advantage was taken of this fact to redesign them in accordance with the most advanced practice. This work was planned by the Works Manager himself in conjunction with his Melting-shop Manager, and was not referred to the committee. The change in design of the furnaces, however, was expected to increase considerably their rate of working, and this expectation was fully realised.

The shop had originally been designed for, and equipped with, two 50-ton and one 25-ton furnace, and had been enlarged in two stages. First, two 60-ton furnaces were added to the equipment and a small extension was made to the shop. Then the capacity of all the furnaces was increased. The total effect of these two changes was that the nominal furnace capacity was increased by more than 150 per cent. Re-designing the furnaces, so as to increase the rate of working, was capable of increasing the number of casts obtainable per week by about 25 per cent., without, however, increasing the size of the individual casts.

Owing to the requirement for higher-quality steels, the casting practice had also changed since the shop was built. Originally ingots were direct teemed—that is, the liquid steel was run into the ingot moulds from the tops, which were open. Now, in the case of at least 60 per cent. of it, the steel was led into the moulds from the bottom through refractory-lined runners; this complicated and increased considerably the time necessary for the operation of setting up the moulds ready for teeming. Again, many of the moulds had now to be fitted with feeder heads which consisted of castings lined with refractory material placed on top of the moulds, and were designed to hold a reservoir of liquid steel to fill the space left by the shrinkage of the ingot in cooling.

As against these changes, which increased the time and amount of work necessary in preparing the moulds to receive the steel, improvement had been made in the steel ladle to reduce the time of “teeming.” Instead of one nozzle at the bottom of the ladle, to fill one mould (or batch of moulds) at once, two nozzles had been fitted, so that two moulds could be filled at once.

The crane equipment of the casting-shop was one 85-ton (formerly 75-ton) and one 100-ton ladle crane; on the same gantry was a 10-ton crane used for stripping, and on another gantry above were two other cranes, one of 15 tons and the other of 20 tons capacity. The stage was equipped with two 3-ton charging cranes and one 40-ton general purpose crane.

Drawbacks of Shop.—The difficulties under which the shop operated, and from which the committee were required to find relief, mostly manifested themselves in delays to furnaces;

if these could be eliminated, the cost of steel-making could be reduced. They may be summarised as follows (Fig. 59) :—

(A) **Casting Shop.**—The increase of number and capacity of the furnaces, and the changes in the manner of casting, had so increased the amount of work, and the amount of equipment that had necessarily to be kept at hand, that there was not sufficient room in the casting-shop to carry out all the operations in the time available; it was discovered in the course of the investigation, from time studies, that if room were provided the crane equipment would be insufficient. When four furnaces were in operation, delays were considerable, and to operate five (which seemed necessary from other considerations) would have been impossible. Added to this was the fact that, besides being too narrow, the crane gantry was too short, a condition that involved danger of considerable loss in case of a breakdown to one of the ladle cranes; each of the end furnaces could only be served by one of the cranes, and if this one broke down the other one could not get into position to do its work. Also, one of the cranes—the 85-ton one—was too light to tap a 70-ton charge; the cure for this was obvious.

Certain of the work done had to be dried by fire before use, which gave rise to smoke that limited the crane drivers' vision.

(B) **The Stage.**—Leading on to the stage were two tracks, on which travelled bogies, each carrying four pans; one track was reserved for acid materials and the other for basic. At the entrance to each of these tracks was a weigh-bridge, on which the bogies with loaded pans were weighed on entering, and tared on leaving with empty pans, thus giving a record of the weight and character of the material delivered to each furnace. All bogies had to enter and leave the shop at one end.

The length of each track was insufficient to accommodate sufficient bogies to carry complete charges for the furnaces that required to be charged at the same time, and it was the practice to divide the charge into three and sometimes four trains. If two furnaces were charging at about the same time, the furnace that finished charging first had to wait for its next train of bogies until the other one had also finished.

There was then a further interval while the empty bogies were weighed, taken off, returned to the scrapyard, and full

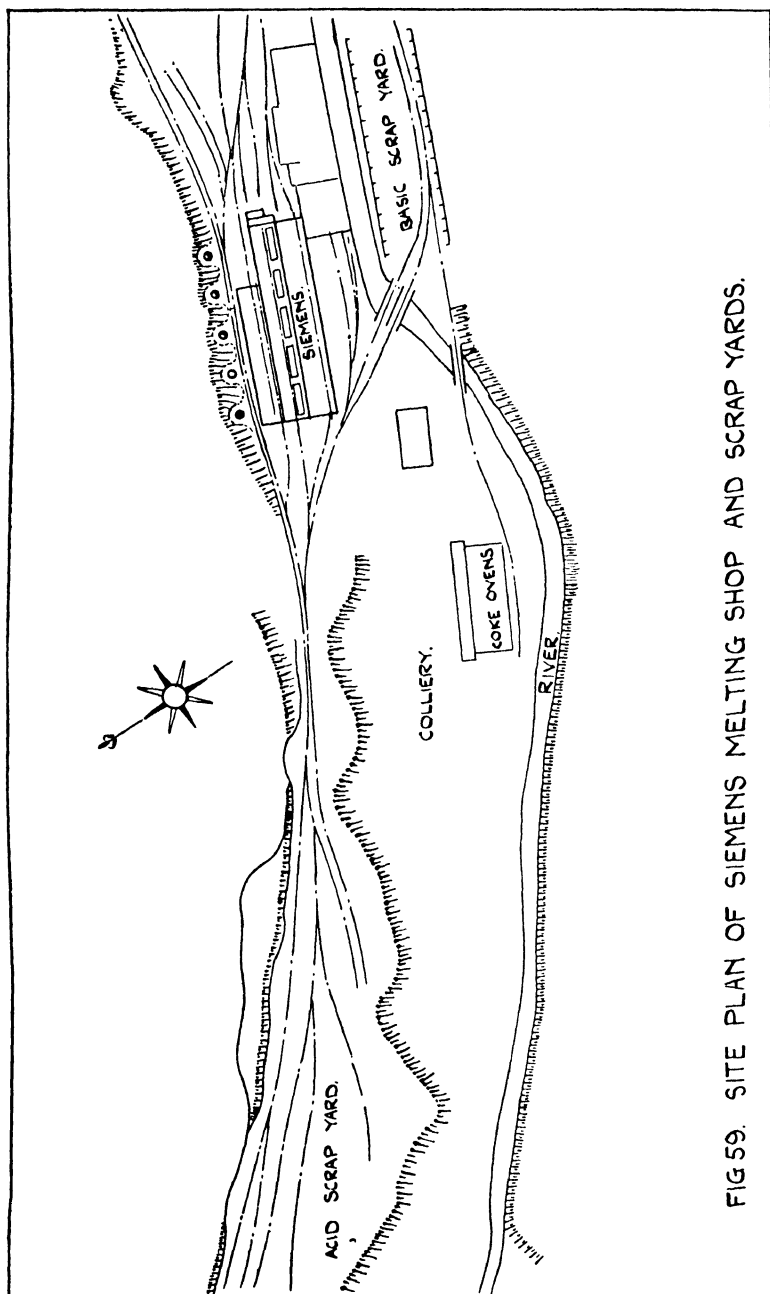


FIG. 59. SITE PLAN OF SIEMENS MELTING SHOP AND SCRAP YARDS.

bogies brought and weighed on; the track space just outside the shop was insufficient to permit the storage of the replace charges. The total of these delays was considerable.

This position was somewhat aggravated by the need to bring fluxes, etc., on to the stage as required for use. These materials could not be stored on the stage because the charging cranes swept within about 9" of it.

Both these materials and the scrap and pig iron came from storage places that were widely separated, and situated some distance from the shop.

The Investigation.—The difficulties were taken one at a time, and usually, once the problem had been clearly stated, a suggestion for solving it was forthcoming. Sometimes time studies were necessary to evaluate the difficulties. If, after examination and discussion, the proposed solution seemed to be acceptable, it was tested by time studies.

In the course of the discussion, records giving statistics of production, wages and raw materials, and cost figures of past periods, were studied, and wherever necessary new time studies were made and analysed.

In the case of the casting-pit, obviously more room was required. Lengthening the shop at each end would give some relief, and would overcome one of the crane difficulties. The other could be overcome by replacing the 85-ton crane by a new one of 100 tons capacity. The additional room gained by lengthening the shop was limited and insufficient. Moreover, it would not be in the right place for the operations of setting the moulds, and it was obvious that more width was required.

To widen the shop would be to reconstruct it almost completely, and this was quickly ruled out as too costly and difficult.

Finally it was suggested that a new bay should be built alongside the casting-shop, and that all the auxiliary work for the casting-pit should be carried out in it. This work consisted of relining feeder heads and tundishes, preparing "trumpets" (which were really funnels leading into the horizontal ducts that fed the moulds with liquid steel from the bottom), drying all these, and keeping them warm to be ready for use (Figs. 60 and 61).

In order that this proposal could be thoroughly examined,

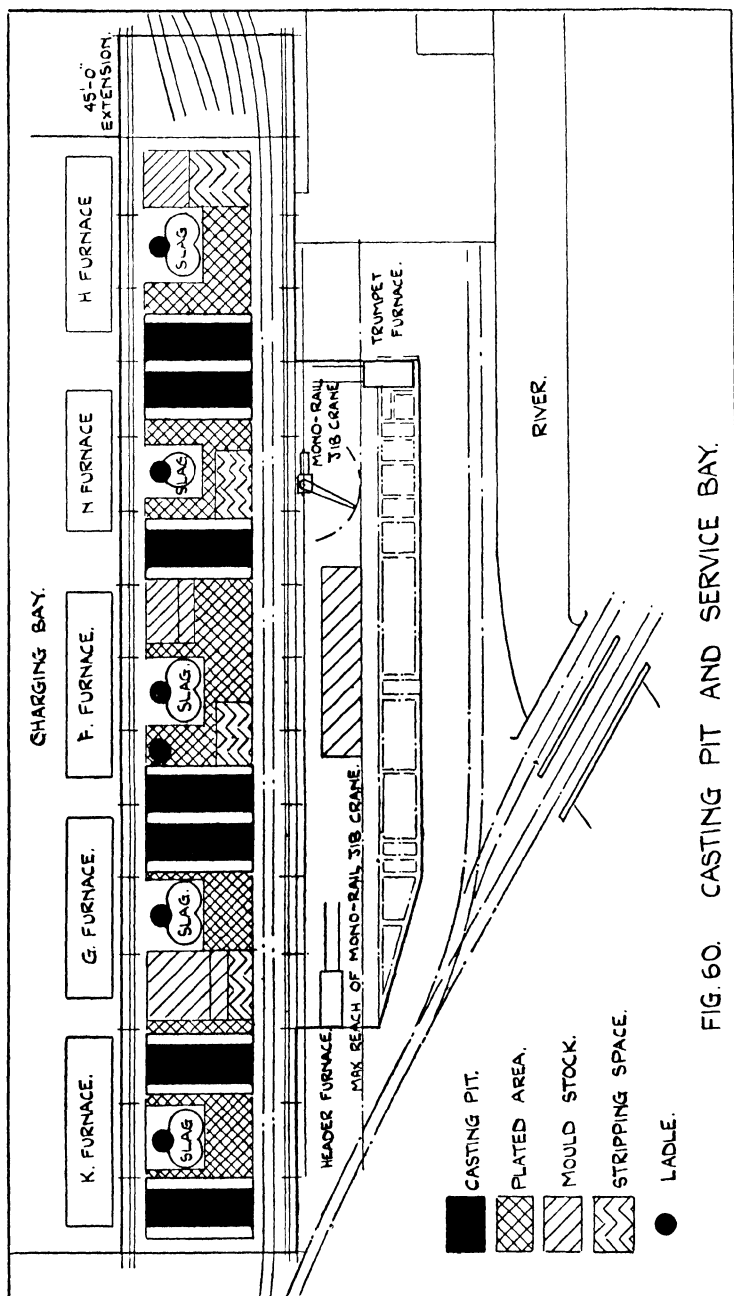


FIG. 60. CASTING PIT AND SERVICE BAY.

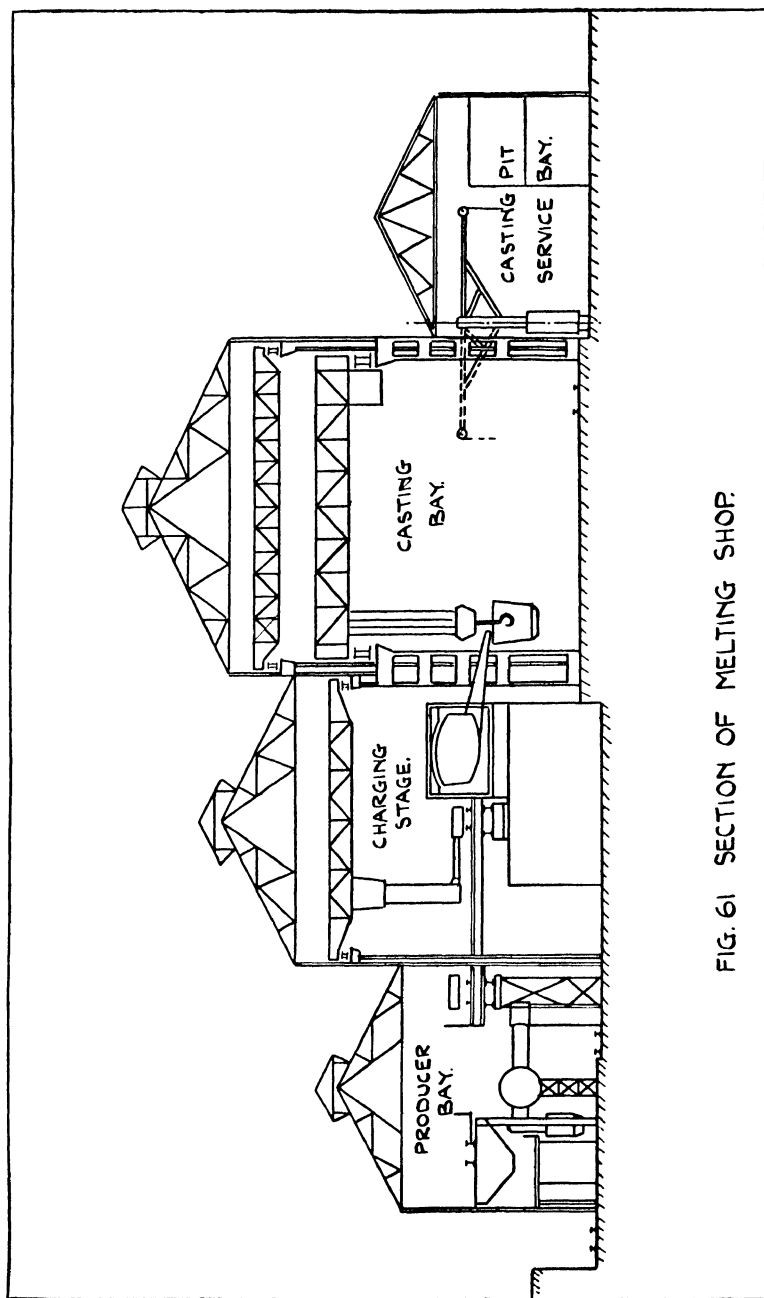


FIG. 61 SECTION OF MELTING SHOP.

two steps were necessary : first, to find out, from the total life and the repairing periods necessary, during how many weeks of the year the various furnaces could be available for work, and, consequently, what quantities of the different casting components would be required. Secondly, to determine the dimensions and layout of the auxiliary shop, and what equipment would be required. It was also necessary to decide upon the positions of the casting-pits, stripping spaces, mould-stands and ladle-stands in the casting-shop, and this involved time studies of various operations.

The calculation of the working periods of the furnaces is given below as an example of the manner in which such calculations were made.

Furnace Working Time.—A furnace has a working life of 26 weeks, after which it is “rebuilt,” which takes approximately 16 days. Midway in its life or “campaign” it is shut down for midway repairs, which take 10 days.

Two cases were considered, case 1 in which all five furnaces were rebuilt in sequence, and case 2 in which the repairs are permitted to overlap. (See Fig. 62.)

Case 1.—A year consists of 50 working weeks, 2 weeks being used for general repairs to plant; therefore it was assumed that two of the repairs would be arranged to coincide with the two stop weeks.

The time per furnace for midway repairs was 10 days, therefore the period during which only four furnaces are working due to midway repairs is $2 \times 5 \times 10 = 100$ days. The time per furnace for complete rebuild is 16 days, therefore the period during which only four furnaces are working due to complete rebuild is $2 \times 5 \times 16 = 160$ days.

The total period during which four furnaces are working due to midway repairs and complete rebuilds $= 160 + 100 = 260$ days. Fourteen days of this period coincide with the two stop weeks, during which no furnaces are working. Therefore, the total period during which four furnaces are working is 246 days $= 35$ weeks. Five furnaces working period is $351 - 246 = 105$ days $= 15$ weeks.

Case 2.—Assume the year commenced with one of the furnaces being shut down for a complete rebuild, which takes 16 days; 7 days later a second furnace shuts down for a

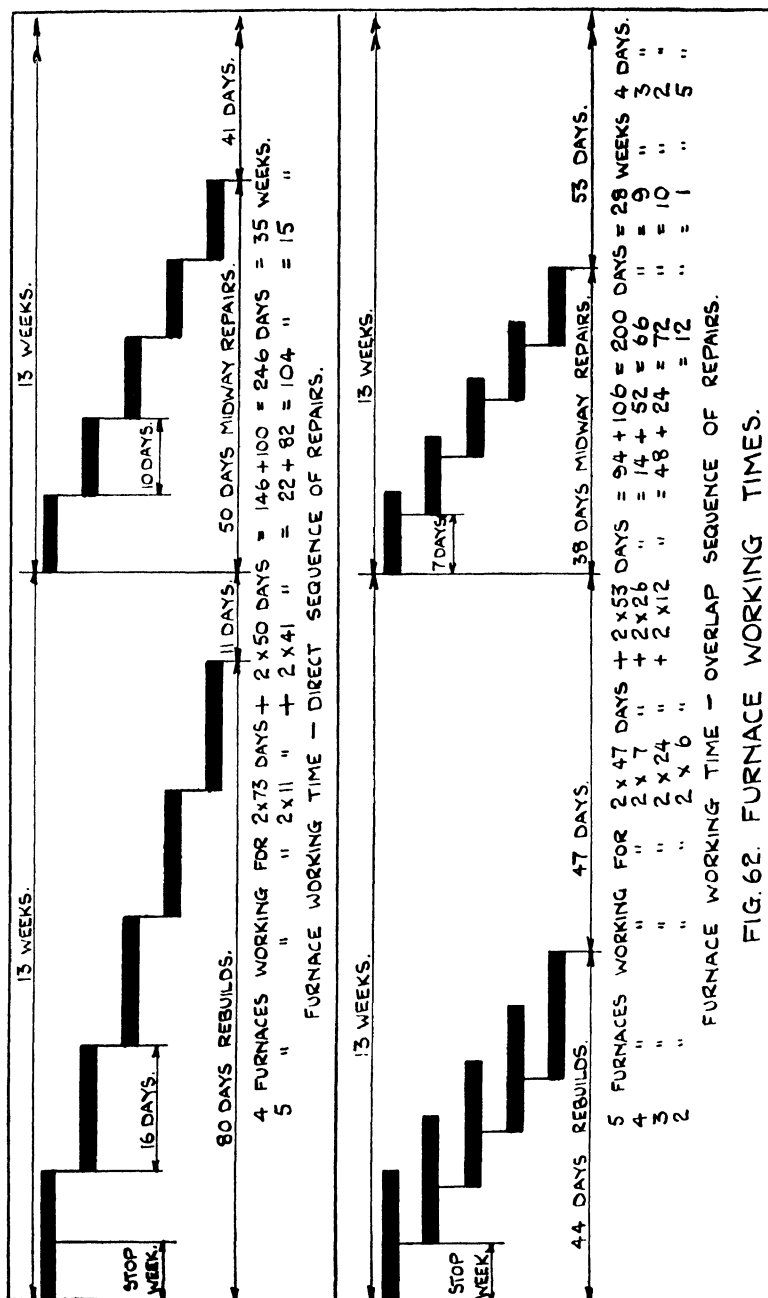


FIG. 62. FURNACE WORKING TIMES.

complete rebuild, and each successive 7 days another furnace is shut down.

From this it is seen that the rebuilding of the five furnaces is spread over $4 \times 7 + 16 = 44$ days. Thirteen weeks after being rebuilt, each of them is shut down for a midway repair. It follows that between the completion of the rebuilding and the commencement of the midway repairs—a period of 63 days ($\frac{26 \times 7}{2} - 44 + 16$)—5 furnaces are available.

The midway repairs run in the same sequence as the complete rebuilds, *i.e.* one furnace 7 days after the previous one and spread over 38 days ($4 \times 7 + 10$). Thirteen weeks after the completion of the midway repairs, the rebuilding for the second time commences, and so five furnaces are available for $(91 - 28)$ or 63 days. The sequence of rebuilding detailed above is now repeated, and again spreads over 44 days. Then each furnace now works for a further 13 weeks, and, as before, five furnaces are available for 63 days of this time. The second set of midway repairs now follows, and spreads as before over 38 days, and then 5 furnaces are available for the remainder of the year, *i.e.* 12 days. The lower part of Fig. 62 shows this complete sequence, and the results can be stated as follows :—

RUNS BETWEEN REPAIRS.

	5 Furnaces, days.	4 Furnaces, days.	3 Furnaces, days.	2 Furnaces, days.
1st run . . .	63	14	24	6
2nd „ . . .	63	26	12	—
3rd „ . . .	63	14	24	6
4th „ . . .	12	26	12	—
Total . . .	201	80	72	12

From the foregoing it was found that :—

If it is assumed that all the repairs to the furnaces occur in direct sequence one at a time (case 1), five furnaces are available for work together for 15 weeks of the year, and 4 furnaces for 35 weeks of the year, making a total of $(5 \times 15) + (4 \times 35)$ or 215 furnace weeks per year.

When the repairs overlap each other (case 2) 5 furnaces can

work together for 28 weeks, four furnaces for 11 weeks, 3 furnaces for 10 weeks, and 2 furnaces working for 1 week, making, again, a total of 215 furnace weeks per year. This calculation formed the basis of several other determinations.

The Service Shop.—With regard to the dimensions of the service shop, the maximum length and the maximum width were fixed by the length of the casting shop itself, and by the existence of railway tracks that could not be dispensed with, and the necessity to provide suitable stores for various kinds of refractory bricks and materials, and road and rail access to them. It therefore became a case of choosing the equipment necessary, designing the furnaces for drying, and laying these out in the space available, with due regard to the stores of the particular refractories required. It was also found possible to set aside standing room for certain moulds that were not in regular use, but were used too frequently to make it desirable to take them away from the shop altogether. A means of transferring these and other materials into the casting-shop readily and conveniently was required, and for this a walking jib crane was selected that would reach sufficiently far into the casting shop, and command sufficient of the auxiliary shop, to enable it to be used for some of the operations there.

The Casting Shop.—In laying out the casting shop itself, a casting pit, stripping space and mould stocking space was assigned to each furnace, and a spare casting pit to be kept set up for emergency use was provided (Figs. 60 and 61).

Equipment and Operating Generally.—The adequacy of each piece of equipment, and the possibility of working all the operations for the maximum capacity required, were tested by taking time studies of the separate processes as carried out at the time, and preparing schedules of operations as they would be.

An example, typical of the rest, is shown in the time studies of pit setting and crane work. This is best described with reference to the diagrams that were made.

Having obtained from detailed studies of the various operations the necessary time data, a diagram was made, Fig. 63, the upper part of which shows to time scale the complete cycle of operations in making an uphill cast with feeder heads, and also the activity of the cranes. It will be seen that the ladle-crane

was occupied during tapping and teeming a total of 50 minutes, and the stripping-crane for 7 hours 12 minutes. In some cases it was possible to carry out two operations at once; for example the preparation of clay could be done while the ingots were cooling; the cleaning and bricking of bottom plates could be done while the crane was engaged in stripping and dismantling the mould set-up. Slag could be removed with the crane, when not occupied, and the moulds could at the same time be tarred inside.

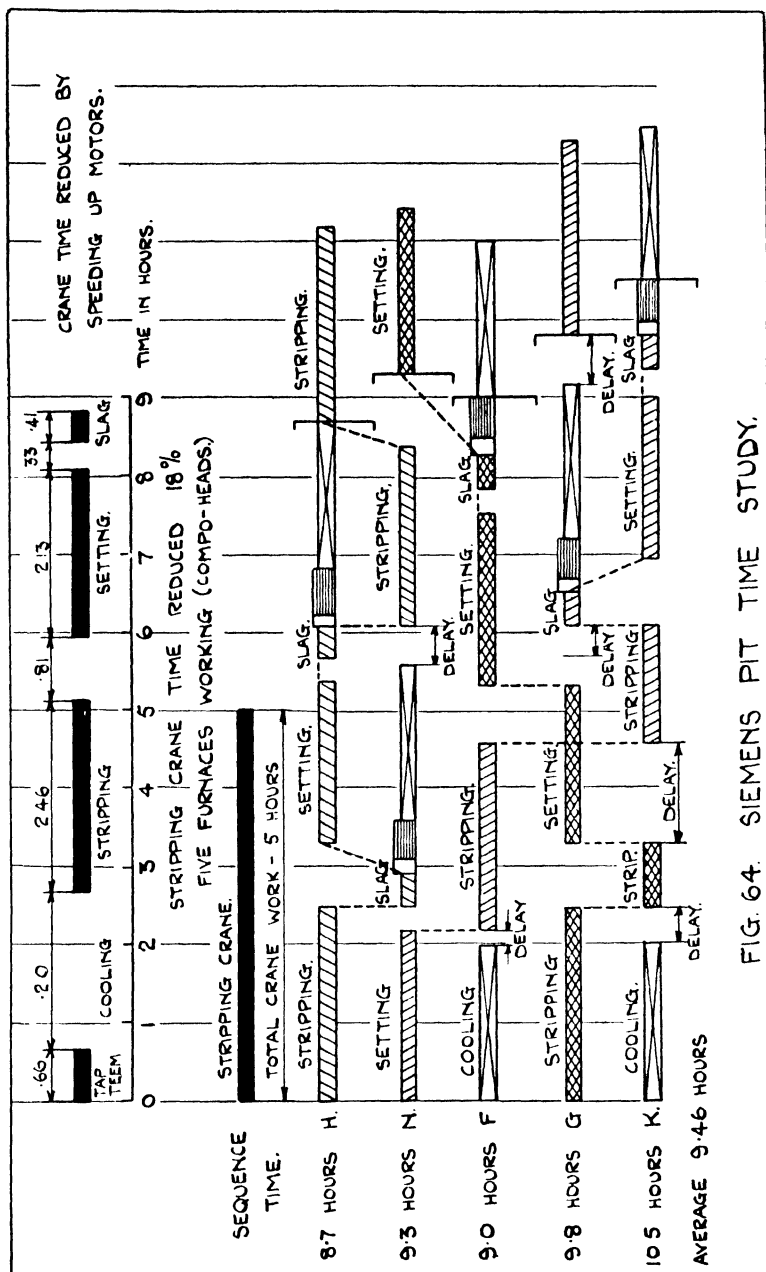
When the processes were able to proceed without delay, the cycle could be completed in 10 hours 54 minutes. Moreover, when the working of the five furnaces with three stripping-cranes was set out, it was seen that the crane service was insufficient, and delays occurred which caused the cycle time for the five furnaces to average 12·94 hours. This is shown in the lower part of Fig. 63.

The maximum time that could be allowed in order that the output schedule would be complied with was 10 hours, and some way of reducing the cycle times had to be found. Two of the stripping-cranes—the 15-ton and the 10-ton—were much slower than the third, but examination showed that these could be speeded up by changing the motors.

A new diagram—Fig. 64—was drawn, showing, as before, in the upper part, a complete cycle for one furnace, and below the crane work for the operation of the five furnaces. The change to the crane motors had reduced the time taken by the work of the stripping-crane by 18 per cent., and this made it possible for the cycles to be carried out in 9·46 hours on the average, with a maximum of 10½ hours. It will be noted that for this test maximum conditions were taken—namely, an uphill cast with feeder heads. Casts that were directly teemed, or with which no feeder heads were used, had correspondingly shorter cycles; consequently there was a small margin in the crane activity calculated in this way.

The foregoing gives a fair indication of the methods used in the examination of the problems of the casting-shop, and its services.

Operating Stage.—There remained the problem of supplying the furnaces with raw materials, and this involved unloading wagons, sometimes into stock (because some of the materials



came into the works very irregularly), sometimes direct into pans, then filling the pans from stock, transferring the pans on bogies to the shop, and, finally, weighing and placing into position on the stage for charging. Of the many studies made in the attempt to solve this problem, the one which dealt with the filling of charging-boxes, and also with the unloading of material from wagons, which had necessarily to be done with the same apparatus, is typical, and is described below.

Pan Filling and Charging.—In order to determine the number of charging-pans that would have to be handled, statistics of the weights of various materials that could be contained in a charging-pan were collected over a sufficiently long period, and the following averages were obtained :—

<i>Basic.</i>						
Pig Iron	.	.	.	.	.	36 cwts. per pan.
Scrap Metal	.	.	.	.	.	8½ " "
Lime	.	.	.	.	.	11 " "
Ferro Manganese	.	.	.	.	.	20 " "
<i>Acid.</i>						
Pig Iron	.	.	.	.	.	44 " "
Bought Acid Scrap	.	.	.	.	.	11½ " "
Bought Acid Light Scrap	.	.	.	.	.	5½ " "
Own Acid Scrap	.	.	.	.	.	34 " "
Bought Tubes	.	.	.	.	.	11½ " "

Time studies were then taken of the loading of pans. Basic scrap and pig were loaded by an electric overhead crane with magnet; acid scrap by a steam crane with magnet, and acid pig by hand. The average times obtained are as follows :—

Cast Iron Basic	.	.	.	.	2.27 minutes per pan.
Scrap Steel Basic	.	.	.	.	1.72 " "
Pig Iron Basic	.	.	.	.	2.75 " "
Scrap Steel Acid	.	.	.	.	3.10 " "
Pig Iron Acid	.	.	.	.	5.89 " "

It was then necessary to find out if the cranes could handle sufficient material for all five furnaces during the week, in the time available.

As a basis of requirements, the following data, which seemed to represent maximum requirements, were taken, and loading times per week calculated :—

Furnace.	Charge per week.	Pans per charge.	Pans per week.	Loading time per week, minutes.
H	14	5 pans pig 11 „ cast iron 120 „ scrap	70 154 1680	192.5 349.5 2890 <hr/> 3432.0
F	13	5 pans pig 11 „ cast iron 120 „ scrap	65 143 1560	179 324.5 2680.0 <hr/> 3183.5
K	13	11 pans pig 68 „ scrap	143 884	843 hand 2740
G	13	8 pans pig 52 „ scrap	104 676	613 hand 2095
N	13	8 pans pig 24 „ scrap	104 312	613 hand 967

The total weekly loading time for basic furnaces H and F = 3432 minutes + 3183 minutes = 6615 minutes, or 110 hours 15 minutes.

The total weekly loading times for the acid furnaces N, G and K were :—

The Hand-loading Acid Pig = 843 + 613 + 613 minutes = 2069 minutes, or 34 hours 29 minutes.

The Magnet-loading Acid Scrap = 2740 + 2095 + 967 minutes = 5802 minutes, or 96 hours 42 minutes.

Unloading of Materials.—In order to test the adequacy of each method of handling by comparing the capacity with the total requirement, it was now necessary to obtain corresponding information as to the time taken in unloading materials from wagons.

Studies were made of the unloading of the various materials, and the following unit times were found :—

Basic Pig Iron . . .	0.72 minutes per ton by magnet crane.
Basic Cast Iron . . .	1.00 „ „ „ „ „
Basic Scrap Steel . . .	1.97 „ „ „ „ „
Acid Pig Iron . . .	2.68 „ „ „ hand.
Acid Scrap Steel . . .	2.15 „ „ „ magnet crane.

Taking the same charges as those used for the pan-filling calculation, the requirements were as follows :—

Furnace.	Material.	Weight, tons.	Tons per week.
H	Pig Iron	9	126
	Cast Iron	12.5	175
	Scrap Steel	52	728
F	Pig Iron	9	117
	Cast Iron	12.5	162.5
	Scrap Steel	52	676
K	Pig Iron	24	312
	Scrap Steel	47.4	616
G	Pig Iron	17.6	229
	Scrap Steel	33.7	438
N	Pig Iron	17.6	229
	Scrap Steel	21.4	278

The unloading time for basic material was found to be :—

	Tons per week.	Mins. per week.
Basic Scrap Steel .	1404	2768
Cast Iron . . .	337.5	337.5
Pig Iron . . .	243	175
Total . . .	1984.5	3280.5 = 54 hrs. 40.5 mins.

and for acid materials :—

	Tons per week.	Mins. per week.
Acid Scrap Steel .	1332	2865 = 47 hrs. 45 mins.
Pig Iron . . .	770	2060 = 34 hrs. 20 mins.
	2102	4925 = 82 hrs. 5 mins.

It has been shown that the basic crane would have to load material into pans for 110 hours 15 minutes per week and unload material from wagons to stock for 54 hours 41 minutes, giving a total working time of 164 hours 56 minutes. Thus for two basic furnaces working, the basic crane would have to work 165 hours, which was longer than the available time.

It was obvious, therefore, that part of the basic material would have to be loaded direct from wagons into pans, and the layout of the scrapyard would have to be such as to permit of this being done in shorter time than by the two processes of unloading out of wagons into stock, and out of stock into pans.

In the same way, the acid crane would have to work $144\frac{1}{2}$ hours per week when all the acid furnaces were working; in addition, the unloading and loading by hand of acid pig would take 69 hours per week.

Cranes and Furnaces.—It was then necessary to determine how the cranes would work in conjunction with the furnaces.

The stipulated charging times for the furnaces were :—

H.	N.	F.	G.	K.
3 hrs.	2 hrs.	$3\frac{1}{2}$ hrs.	$2\frac{1}{2}$ hrs.	3 hrs.

BASIC.—The two basic furnaces H and F would cause the greatest demand if they both charged together. In order to find the time at which it would be necessary to commence loading pans for any case where H and F commenced to charge together, it was necessary to start with the last train of pans charged and work backwards. With these two furnaces, iron is the last material charged.

H FURNACE.—From time studies, the charging-machines took 15 minutes to charge the last run of iron, and 18 minutes was the travelling time to bring the pans from the stockyard to the chargers, a total of 33 minutes; deducting this time from a total charging time of 3 hours, it was evident that all the iron for H furnace must be ready loaded into pans 2 hours 27 minutes after the commencement of the charge.

The loading of iron for H took the following time : 5 pans of pig iron at 2·75 minutes per pan = 13·75 minutes. 11 pans of cast iron at 2·27 minutes per pan = 24·97 minutes. Total 38·72 minutes—say, 39 minutes.

Therefore loading iron must commence not more than 1 hour 48 minutes (2 hours 27 minutes — 39 minutes) after the commencement of the charge.

F FURNACE.—On F furnace, the charging-machines required 20 minutes for charging the last run of iron, and 16 minutes was the travelling time required to bring the pans from the stockyard

to the chargers, giving a total of 36 minutes; deducting this time from a total charging time of $3\frac{1}{2}$ hours, it was evident that all the iron for F must be loaded into pans not later than 2 hours 54 minutes after commencing to charge scrap.

WORKING H AND F LOADING TOGETHER.—The time available for loading iron for F, between the end of loading iron for H and the required finish of loading time for F iron, was 2 hours 54 minutes — 2 hours 27 minutes = 27 minutes.

However, the total iron loading time for F was the same as for H, *i.e.* 39 minutes. Therefore, as F iron could not be loaded at the same time as H iron, it followed that the loading of the remainder of F iron must commence 12 minutes (39 minutes — 27 minutes) before the commencement of the loading of iron for H.

As it has been assumed that H and F commence charging together, and as it has been found that the loading of iron for H must commence 1 hour 48 minutes after the commencement of the charge, the time available, during charging, for the loading of H and F scrap is 1 hour 48 minutes — 12 minutes = 1 hour 36 minutes. At the rate of 1.72 minutes per pan for basic scrap loading, this time is equivalent to 56 pans.

The total number of scrap pans required for the charging of H and F furnaces is 238. Therefore it was necessary to have $238 - 56 = 182$ pans of scrap ready loaded before charging commences. At the rate of 1.72 minutes per pan, this number is equivalent to a time of 5 hours 13 minutes. Therefore the basic cranes in the stockyard must commence loading the basic charges of H and F 5 hours 13 minutes before the commencement of the actual charging, when H and F commence together, and there must be room for a stock of 182 pans, which is equivalent to 46 bogies.

ACID.—The stipulated charging times for the three acid furnaces have been given as :—

$$G = 2\frac{1}{2} \text{ hours. } H = 3 \text{ hours. } N = 2 \text{ hours.}$$

In finding the time at which it was necessary to commence loading pans for charging, the worst case was taken as before—namely, that of G and K commencing to charge together, and N commencing 50 minutes later. The reason for the latter period or gap was that there were only two tapping

cranes available, and the minimum time for tapping, teeming and change over was 50 minutes; therefore if two furnaces began to tap at the same time, a third could not begin to tap until 50 minutes later.

As with the basic loading, the method of calculation was to start with the final run of charging and work backwards, fitting in the loading for the respective furnaces as the cranes become available.

If, for convenience, the commencement of G and K charging time is called zero, then G finishes charging $2\frac{1}{2}$ hours after zero, K 3 hours after, and N 2 hours 50 minutes after.

The times for charging the last runs on G, K and N are 24, 24 and 12 minutes respectively. The travelling time for bringing the first pans from the stockyard to the stage is 20 minutes on each furnace, therefore the intervals of time between the end of charging and the end of loading in G, K and N are 44, 44 and 32 minutes respectively.

Deducting these times from their respective total charging times and making a reduction of 6 minutes in the total charging time of G, due to two chargers being available, the times from zero to the end of the loading time of G, K and N are 1 hour 40 minutes, 2 hours 16 minutes and 2 hours 18 minutes respectively. Therefore, the time available for loading during charging time is 2 hours 18 minutes, which has to be divided amongst the three furnaces.

Scrap is the last material to be charged on the acid furnace. At the loading rate of 3.1 minutes per pan, 2 hours 18 minutes is equivalent to 44 pans. The total number of pans of acid scrap required for the three charges is 144, $(68 + 52 + 24)$, which takes 7 hours 26 minutes to load. Therefore scrap-loading must commence 7 hours 26 minutes — 2 hours 18 minutes or 5 hours 8 minutes before charging commences, accumulating 100 pans.

The total number of pans of acid iron is 27, $(11 + 8 + 8)$, which at a rate of 5.89 minutes per pan takes 2 hours 39 minutes to load. Therefore, the loading of the acid charges must commence 7 hours 47 minutes, $(5 \text{ hours } 8 \text{ minutes} + 2 \text{ hours } 39 \text{ minutes})$ before charging begins, and there must be accumulated a stock of 127 pans, $(100 + 27)$ which would require 132 bogies.

The position as to the filling of charging-pans can be stated thus : taking the most difficult case—that is, when the furnaces tap in a direct sequence of two, commencing with the two largest furnaces—the crane for basic scrap must commence loading H and F charges 5 hours 13 minutes before the actual charging begins, and the crane for acid scrap 7 hours 47 minutes before charging begins on the acid furnaces, in order to keep within the stipulated charging times. These times are equivalent to a basic-pan stock of 182 pans, or 46 bogies, and an acid-pan stock of 126 pans or 32 bogies, when charging commences on basic or acid furnaces respectively.

With the two basic furnaces working, 27 per cent. of the scrap required for a full week's work must be loaded direct from wagons into pans.

With three acid furnaces working, the crane in the acid yard can cope with the unloading and loading of scrap, and three men per shift are required for handling the scrap and unloading and loading the acid pig iron.

Proposals. (a) Telfer.—When the consideration of this problem was first undertaken, there was a strong impression that the time taken to get material into the shop, including the weighing of the loaded and empty pans, was the most important factor, and that the governing cause was that the trains all had to enter and leave the shop the same way. Since there was no possibility of obtaining an entrance to or exit from the shop at the other end, the search was for a means of doing this in another way, and a system of telfers was proposed. Up to this time it had been considered necessary to keep acid material entirely separated from basic materials, and so the first proposal was for two completely separate circuits, one connecting the basic stockyard with the stage, and the other the acid stockyard. This proposal was carefully examined and found to have certain disadvantages, besides being very costly. It was next suggested that the site on which the acid scrapyard was situated could be so laid out that there was room for both the basic scrap and the acid scrap in separate stocks side by side.

The traffic in the scrapyards would be on railway tracks, and not by telfer; consequently the telfer track and supporting structure were considerably shorter. This made the

loaded pans more accessible to the shop; it made it possible to arrange a weighing station in each yard, and to obtain both the loaded and tare weights on one machine; it unified the control of the stockyards, and made it possible for one man in a central cabin to control all material supplied to the stage; it reduced the manning and increased the capacity of the stockyards. This proposal was worked out and tested in detail, and found to comply with every requirement.

On the other hand, the capital cost was very heavy, and it seemed worth while to see if a simpler and less costly solution could not be found.

(b) **Stage Widening.**—Two other proposals were examined. One was to widen the stage of the melting-shop, and use the additional space thus obtained to fill charging-pans direct from wagons of scrap, by means of overhead cranes with magnets, and only use the stockyards for unloading scrap when it came faster than it could be used. This arrangement was still costly, but less so than the telpher.

(c) **Double-Deck Bogie.**—The other proposal was to use double-decked bogies for the charging-pans, and thus double the capacity of the tracks leading to the stage. This would have required that the charging-cranes should be capable of lifting a charging-box from each of two different levels.

(d) **Revision of Railways.**—Both these proposals proved to be feasible and to fill the requirements. The latter (c) was rather less costly than either of the other two—(a) and (b). In examining these proposals in detail, it emerged that both of them would require that the storage capacity of the sidings at the entrance to the shop would have to be increased; this further led to the realisation that most of the delay in getting wagons on and off the stage was caused by the necessity of double weighing; the avoidance of this delay by the transfer of the weigh-bridges to the two stockyards had always seemed objectionable, for several reasons. A proposal for the revision of these railway lines was prepared. It involved filling up a dip in the road to level out (the entrance to the shop was at the top of a 1 in 25 incline), providing additional storage sidings, and additional roads to the two stockyards. The development of this arrangement showed the way to placing a single weigh-bridge in a piece of track common to the acid and basic roads,

and thus to make it possible to weigh the material before it was put into the storage sidings. The effect of this was that empty wagons could be drawn from the stage and replaced by previously prepared full ones in about five minutes, and no doubt it was felt that this would solve the problem. In any case, the other proposals would still be available if it was found that any delay remained.

This proposal included a store for alloys on the stage extended; an elevator to enable refractory bricks for furnace rebuilding to be brought up from beneath the stage where they were stored, instead of running them round by railway; and storage sidings for coal and other minerals and fluxes, with covering-sheds to protect such as could not be exposed to the weather.

This concluded the investigation for the time, and the following recommendations were made.

Recommendations: Casting Shop.—This was to be extended in length, and the 85-ton crane replaced by one of 100 tons capacity. The 15- and 20-ton cranes to be fitted with faster motors. The shop to be replanned, providing a separate space for each operation, and a place for the storage of each piece of plant when not in use.

Service Shop.—A service shop to be built alongside the casting shop to contain heated stores for refractory bricks used in ingot casting; plant provided for relining feeder heads consisting of jolt rammer and furnaces for drying; space and bench for relining “trumpets” and furnaces for drying them; and space for relining tundishes. Small repairs to feeder heads were to be executed as before in the casting-shop. Special moulds were to be stored in the service bay; a walking jib-crane was to be provided to pick up moulds or trays containing heads or trumpets to be relined from the pit and hand them in the service bay, or *vice versa*; and an auxiliary jib-crane to serve the jolt-ramming machine.

Stage. Raw Material Supplies.—A new charging crane to be erected, making three in all. The railways serving the shop to be reconstructed in such a way as to provide a circuit from each of the two stockyards substantially isolated from other traffic; there were to be sufficient marshalling and storage sidings to contain material for at least two-thirds of two

charges for either or both acid and basic furnaces, with weighing facilities at the entrance to these sidings; storage sidings near to the shop for coal, fluxes, etc., with sheds for material requiring protection from weather; the existing 1 in 25 grade at the entrance to the shop was to be flattened out to not more than 1 in 200; a store for alloys was to be constructed on the stage extended, and an elevator for bricks to connect this extension with the brick stores.

Until these changes had been made and tested in practice, other expedients were to be held in abeyance.

These three groups of recommendations, as far as could reasonably be foreseen, complied with all the requirements, viz. to handle without delay the full output of the five furnaces, as they were before reconstruction. Actually, three were reconstructed to the new designs, one was retained and operated under the old conditions, and the other was retained in reserve. The output from the four in operation was equal to the possible output of the five before reconstruction.

Future Outlook.—It will be observed that a comparatively simple and inexpensive method of improving matters on the stage was chosen; first, because it would not prevent, or hamper in any way, the adoption of one or other of the more costly schemes at a later date, if experience with the better conditions produced should show it to be necessary; secondly, because this simple scheme would assist in making it possible to obtain a further improvement by a particular method of organisation, now to be described.

An examination of all available data was made with a view to estimating the possibility of planning the work of the shop on a time basis. A weekly programme was, of course, regularly drawn up, but the changes and delays which occurred were so numerous and so serious that it was realised from the outset that time-planning would be very difficult, and would involve a great deal of preparatory work and preliminary collection of data.

The advantages of time-planning, however, were so considerable, not only as aiding the synchronisation of the melting-shop with the mill, but for economising furnace time, forecasting with greater precision the delivery of particular orders, and avoiding the coincidence of operations that interfered with one

another, that it was thought wise to study the matter with a view rather to future than immediate action.

The complete cycle of operations from "tap to tap" could be divided into four periods—tap and fettle, charge, melt and refine, although there is no definite boundary between them. The many variables in the process, which will be enumerated presently, caused every one of these periods to vary in length. For instance, the making of a particular quality of steel increases the amount of work to be done in fettling and increases this period; this of course would be known when the programme was made, and allowance based on experience could be made for it; the charging time was subject to variation from causes outside the shop; the melting time depended on a number of circumstances, and was affected by the time taken in charging; the refining period depended also on a number of circumstances, including the quality of steel to be made, and even the time taken in melting.

Factors or Variables.—It is worth while listing the principal factors or variables in making a cast of steel that are likely to affect the time cycle of the furnace.

(1) *Weight of the Cast.*—The casts, in the period examined, varied between 58 tons and $74\frac{1}{2}$ tons, with 69.2 tons as average. Within narrow limits this variation of weight is known before the cast is made, and allowance can therefore be made for it provided the data are available. If the data are not available and are unobtainable, this variation could be eliminated by making casts always the same weight.

(2) *Quality of Cast (Analysis)* —At present, there is no precise datum as to the amount, or the rule according to which this variation affects the time. It could be obtained from experience of a large number of casts.

(3) *Raw Material Supplies.*—When the delays referred to above have been eliminated, this variable will disappear, and the charging period can be standardised.

At the time of this study it was the largest variable.

(4) *The Quality of the Raw Material.*—By this is meant the proportion of heavy scrap to light scrap, and so on, which may affect the melting time. This can be determined, and, if necessary, it is not impossible to standardise the proportion; in fact, it is roughly standardised now. The greatest effect of

this variable at the time of the study was on the charging time, due to the fact that the number of pans charged was variable.

(5) *The State of the Furnace*.—Whether a furnace is beginning or finishing its working period will be known when the plan is made, and its effect can be determined beforehand.

(6) *The Calorific Value of the Producer Gas*.—This can be standardised within narrow limits. So also can the temperature, quantity and pressure of air.

(7) *The Calls upon the Charging Machines*.—The prearrangement of this will be one of the advantages of planning.

(8) *The Rate of Working of the Men*.—This factor is found in every operation, and usually it does not present any difficulty.

(9) *The Weather*.—According to the weather the charge will be wet, or dry, or covered with snow. This will always remain a disturbing factor to be contended with.

(10) *Influence of One Furnace on Another*.—This arises from the variation in the time of the first tapping of a week.

(11) *Changes in the Melting Programme*.—Changes in the melting programme arise during the week, owing to urgent orders from customers, delays on one furnace, misfits, etc. It is suggested that planning will be a very valuable method of dealing with this variable.

(12) *Variation in Furnaces*.—Baffling differences are found in the behaviour of furnaces that, so far as is known, are alike. These differences can be caused only by differences of construction or dimension, and their removal can be effected only by the standardisation of every detail and dimension of furnaces, and by building them within standard limits of inaccuracy.

This enumeration shows that the task seems to be the solution of an equation with a series of variables, from a mathematical point of view an impossible one.

Nevertheless, some of the variables can be made constant; and all the necessary figures for the remainder can be determined by the use of extensive production statistics, which give sufficient figures to eliminate the influence of all variables but one, so that this one can be determined from the figures.

At this point the study rested, and the work of standardisation, of collection of statistics, and of elimination still remains to be commenced.

PART III

EXTENDED APPLICATION TO INDUSTRIES AND TO
OTHER ACTIVITIES

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ALMOST everything that has been written in the previous pages has had reference to single industrial units, and little has been said about whole industries. It is found that there is great disparity, both between the units of a particular industry, and between the different industries themselves, in the extent to which what have here been called the principles of the New Management have been applied. It is not the purpose, here, to examine generally the causes of this disparity (some of them are obvious enough), but it will be useful to show how the application of some of the new principles can be broadened, and what will be the effect of doing so.

In this review, it will be convenient to refer to two classes of industries: the newer ones, as, for instance, the automobile and electrical industries, and the older ones, such as coal, iron and steel, shipbuilding, house-building, etc. The following pages refer mainly to the latter group.

The older industries can be said to have arisen from the fundamental needs of the community, to have grown as the community grew, and to have developed up to a point according to the genius or application of those engaged in them. They are sometimes referred to as "basic" industries, because on their development have depended, largely, the origin and development of other industries. Most of them have in common the following characteristics:—

(a) Their prosecution involves considerable natural difficulty.

(b) They are necessarily made up of large, and consequently, heavily capitalised units, organised to a great extent (in accordance with the traditions and conventions that have, up to quite recently, governed all industry) in independent and competitive units.

(c) Beyond a certain residual minimum production outlet, insufficient to enable them to operate economically, they have been exposed to the unrestricted play of the law of supply and demand, and of competition throughout the world.

Thus, arising from the last-mentioned characteristic, these industries experience alternating periods of feverish activity when their productive capacity is insufficient to meet the demands made upon it, and of great slackness of demand when much of the plant is insufficiently occupied to enable even the costs of operation to be recovered.

There is no reason here to attempt to assign causes for, or explanations of these fluctuations, but since they undoubtedly threaten the economic well-being of industries that are of primary importance to the community, and since the natural tendency of such fluctuations—apart from their causes—is to increase rather than diminish in amplitude, it is worth while examining for a moment the other class of industry referred to, the newer industries, of which it can be said that their history has been a story of almost unbroken growth and success, in order to see if anything can be done to check this tendency, or even counter the causes, whatever they may be. These newer industries, amongst which the most noteworthy are the automobile industry and several branches of the electrical industries, originating perhaps in inventions or discoveries rather than the existence of a necessity or demand, owe their growth and success to the fact that they have been able to produce continuously improved articles at continuously reduced prices. A most important factor in this progress has been the fact that it was necessary to develop from the beginning the aids and expedients of management referred to in previous pages. These expedients have been called standardisation, continuous flow of work, or continuity of manufacture, work and time studies and progress planning on a time basis, and it has been shown that wherever they have been used—and there are several instances, since they were developed, of their being used for the rejuvenation of old industries as well as for the planning of new—they have had the effect either of reducing the cost of production, or of increasing the ratio of turnover to investment, or (usually) of both.

It is certain that the more extensive adoption of these methods in some of the older industries will have similar results, which, if not sufficient in amount to eliminate the fluctuations of activity, will mitigate their effects. In order that this suggestion, necessarily vague and indefinite, may be made somewhat more concrete, reference is made below to possibilities in several cases.

(a) **Steel.**—To anyone considering the manufacture of steel solely from a production point of view, the most remarkable feature, especially considering its magnitude, is the variability of the conditions under which it is conducted. This lack of uniformity of conditions is the inevitable consequence, either direct or indirect, of the multiplicity of types, varieties and qualities of the product that are demanded by its users. Steel, in some important branches of the trade, is not a single product, but one of five or six hundred different products, made not to secure five or six hundred different results or to serve that number of different purposes, but to fill perhaps as many as fifty different requirements. One reason for this condition, stated broadly, is the omission of those users of steel who manufacture a standardised product, to standardise their raw materials, and another reason is that steelmakers, either out of pride in their craft, or under economic compulsion, have multiplied to an almost incredible extent the varieties of their product, both by varying its composition, chemically, and by varying its physical structure by changes in the later stages of refining and finishing.

To illustrate the first reason an example may be given. The manufacture of motor cars, a highly organised and standardised industry, has required that all parts shall be of such *dimensions* as to be interchangeable. Advantage has been taken of this to have some components made in other factories and by other people, and in these cases the dimensions and purposes of the components are specified and not the processes of manufacture. The subsidiary manufacturer chooses his own processes of manufacture and the steel and sizes suitable for it. So the steelmaker may be, and actually is, called upon to supply both different types and different sizes of steel for the same purpose, and does so.

This is, of course, of no consequence to the motor

manufacturer, but it is of vital consequence to the steel-maker.

The second reason mentioned hardly needs elaboration or illustration, if one remembers the enormous progress that has been made since the beginning of the century in methods of transport by road, water and air, and remembers also that each stage in this progress has demanded, or has followed from corresponding discoveries or achievements of steelmakers.

There are, of course, large sections of the steel industry in which this multiplicity of varieties of steel does not exist to anything like the same extent, but its effect is universal throughout the steel industry, inasmuch as *every cast of steel is individually made*. Thus the very strong incentive that steelmakers would have had, if they had been able to manufacture a standard product, to stabilise and standardise their processes and operations and all the surrounding conditions, has been lacking.

A brief examination of some of the principal processes will show what effect this deprivation has had on productive efficiency; taken in conjunction with the decided lag in engineering development that often exists, for which the fewness and brevity of the periods of economic prosperity during the past twenty years are chiefly responsible.

Blast Furnaces.—In the manufacture of iron, that is the reduction of ores to metal, either as the first stage in the manufacture of steel, or as the manufacture of a separate product for other purposes, there is a great need to standardise the product. Amongst other reasons, it is now well known and appreciated that the best results as regards output and cost are obtained by maintaining conditions in the furnaces as stable and uniform as possible; and that conditions are best stabilised by standardising composition and physical condition as regards the size and hardness of fuel, and the size and composition of ore, with, of course, uniform temperature, pressure, and quantity of air. Standardisation of size of ore requires crushing, screening, and sometimes sintering (roasting) plants, and the most modern, or most recently modernised plants have this equipment.

Steel-making.—Reference has been made to the variability of steel, and to the fact that each cast of steel is “made” individually. In the open-hearth process, by which most of

the steel is made in this country, there are many other variables, each tending to make the process more difficult, to diffuse the skill of the steelmaker over an unnecessarily wide field, and making the process very uncertain as to time, and therefore very difficult indeed to synchronise with other operations.

The furnaces themselves differ in behaviour, even when they are intended to be of exactly the same dimensions and design; and designs differ considerably in important dimensions. The behaviour of any particular furnace changes during its life, but this is a gradual change, and its amount can be determined and allowed for.

The charges for the furnaces vary in composition, and in the case of "cold" charges, *i.e.*, scrap steel and pig iron, vary also in physical condition; these differences cause the melting time in the case of cold charges, and the refining times in both cases, to vary. The composition and temperature of the fuel gas, and the pressure (draught) and temperature of the air, as well as their relative proportions, are not always as constant as they might be made if the necessity were evident.

When the cast of steel has been made, it is drawn from the furnace and cast into ingots. There are six or seven different ways of doing this, each producing its own effect on the result, and each devised by the steelmaker to produce at minimum cost some special quality desired by the user in the resultant steel.

The Rolling Mill.—Thus the time of arrival of the ingots at the mill is quite uncertain; they may be too early or too late, or just in time to be rolled into the section for which they have been made. They have to be brought to the correct temperature for rolling, and in spite of efforts that have been made, and continue to be made, there is no reliable method of determining if this purpose has been achieved with uniformity, until rolling has commenced. Of course, the soaking-pits (furnaces) can be kept at the correct temperature, and the ingots be allowed to remain in them for such time as experience has shown to be necessary, and this is the method usually adopted. If, however, cold are put in amongst hot ingots, as is very often necessary, this method is vitiated and judgment and great care are necessary.

It is in the design of the mill and its equipment that the lag in engineering development already mentioned is most evident, and judged by standards of to-day, it is, more often than not, a very unrepresentative example of engineering knowledge and skill. This is also partly due to the multiplicity of duties it has to serve. Every conceivable variation of width, thickness or diameter of product, and many of the possible combinations of them are called for by users, and are produced to meet their requirements, often in such small quantities as to be unprofitable to the maker, who has to sell them at an average price. A careful examination with a view to reducing the number of standard sizes would probably be of great benefit to the steelmaker by diminishing the time lost in the mill in various ways—the variety of equipment he must have and maintain, and the amount of stock that someone must keep; all this without depriving the user of any essential service; indeed it might benefit the user by inducing him to reconsider his own side of the case.

Here, then, are a few of the difficulties under which this manufacture is carried on. With a full knowledge of all that is implied in the term *The New Management*, how can these difficulties be reduced or overcome, or their effects mitigated?

First of all, the product should be standardised. A list, as nearly complete as possible, of all the qualities, and combinations of qualities, of steel required for a corresponding list of uses could be drawn up. Then to each of these purposes could be assigned the one or two steels that would best suit them, and so would be built up a list of steels standard for certain purposes. Any other steels called for than those on this list would be treated as special, and be specially made and sold at a special price.

This would require close and complete co-operation between all the steel-using industries and the steelmakers as a body, with, perhaps, the British Standards Institution as the co-ordinating authority. Thus would be continued the extension, already begun, of co-operation from within individual units to the whole industry and beyond.

The next step would be to standardise the whole process of steel-making *for each standard quality of steel to be made*, and the most difficult, but perhaps the most profitable stage in this

would be to discover and fix, by agreement, the most suitable value for each important dimension of the furnaces, recording these dimensions in standard general arrangement and detail drawings, with permissible limits of inaccuracy, just as is done with any other machine. The standard furnaces (there would naturally be several standards for different capacities and products) would be adopted throughout the industry; they would be critically reviewed at stated intervals and altered as experience or discovery dictated. The other variables would be considered in turn, and the most suitable values found in each case, be established, once and for all. Some of these variables, of course, are not and cannot be under perfect control, and so there will always remain scope for the art of the skilled steelmaker, but it will be concentrated on a much smaller range of problems, and will be correspondingly more effective and more successful. The process will become one in which the percentage of errors will automatically be reduced, and the duration of which can be foretold with greater accuracy; cost will be reduced, and the steel-making can be synchronised with other processes.

In the same way, it will be much easier, making only a few qualities of steel, to standardise the correct temperatures for the soaking pits and the correct soaking times for each quality; separate arrangements being made for the pre-heating of cold ingots.

Like the qualities of steel, the number of standard sizes to be rolled in the mill would be reduced by agreement, and this would not only lower the cost of production by saving mill time spent in roll changing, but would reduce the size of stocks necessary either to the steelmaker, his merchant or the user.

Then the fundamental data to form a basis for the design of roll contours, mill bearings, gearing, etc., would be determined once for all—another co-operative task—and used both for the building of new mills and for the improvement of old ones that are still serviceable and cannot be scrapped. This will reduce rolling costs by saving mill time and maintenance charges, and will also make possible greater accuracy of rolling that is becoming so necessary for steel-users.

It will be noted that most of the suggestions made so far arise from the principle of standardisation, and all of them

require a more extended application of the principle of co-operation. The cost of adoption in money would be relatively small, and the efforts necessary would in any case be beneficial and educative.

(b) **Ship-building.**—The development of ship-building in other countries, and diminished international trading, due to the rise of economic nationalism, the breakdown in the mechanism of international payments, and other causes, created great difficulty both in the shipping and the ship-building trades. The lack of freights not only stopped the building of additional ships; it prevented or delayed the replacement of obsolete vessels, and thus prevented full advantage being taken of new developments in ship design and methods of propulsion. Until quite recently, there were more ships than could find employment, in spite of the efforts made to attract freights by the manipulation of rates and in other ways. That portion of the shipping industry engaged in passenger traffic attacked the “selling problem” in the most approved manner by arranging and widely advertising facilities for pleasure travelling, and by catering in enhanced style for the comfort and enjoyment of the passengers attracted by these appeals.

The ship-building industry tried to protect itself by laying idle a certain number of “redundant” shipyards, and thus curtailing the building capacity of the country. This may have been essential in the circumstances, but it had the appearance of a policy of despair. On the other hand, it may have reduced the overhead costs of the industry as a whole for the time being, and may be the first step in a very far-sighted policy. If, or rather when (for it is inevitable that the steady growth of the use and need for shipping will be resumed), the capacity of the remaining yards becomes inadequate for the demands, output can be increased, without opening new yards, by a technical revision of the methods of the industry, and in this way the costs of construction can be permanently reduced. The effect of this will, in some measure, be cumulative, because it will react on the cost of overseas transport. Bearing in mind the principles of management referred to in the first part of this book, it is worth while considering briefly how this may be brought about.

Standardisation.—To the ship-builder or ship-owner who experienced the fiasco of “standard ships” between 1916 and 1918 this word may well be anathema as applied to ship-building. But did this principle fail at that time because it was not applicable, or because a mistake was made in the manner of its application? Most of the standard ships were bad sea boats, and some of them were unseaworthy. Surely this was not because of the methods used in building them, nor because they were all alike. It was because of the shapes of their hulls, or their design. The naval architects and ship-designers of this country are second to none in the world, and all their knowledge and experience in designing the hulls of ships for good sailing qualities, stability, and speed were set aside and subordinated to the designing of hulls that seemed easier and quicker to build. In other words, the standard ships were neither standard in the sense of being “what is approved as good or valuable, and even shown to be necessary by experience and consideration,” nor were they ships, but more or less rectangular boxes with tapered ends. They would not have been either bad sea boats or unseaworthy if the standard designs selected had really been standards.

Apart from this, however, whilst the attempt may have been justified in the circumstances in which it was made, it is extremely doubtful if it can ever be economically practicable to standardise ships in ordinary times. The value of standardising any article from an economic point of view depends upon the number of times the design can be repeated. Ships must vary in beam, draught, and length, according to the routes they ply and the trades they engage in. The total number of ships built in any one year is not large, and allowing for the variations referred to, the number called for to any one design must necessarily be small.

But the standardisation of hulls does not exhaust the possibilities of applying this principle to ships; it does not even touch the most important and profitable application—namely, the parts of ships.

In any one ship, if the pitch of rivets be standardised, a large proportion of the deck and hull plating can be made interchangeable, or so nearly so that a little flexibility in the drilling or punching machines will enable it to be made as

quickly and cheaply as though it were interchangeable. A large proportion of the frames, bulkheads, transverse members, and other parts can be interchangeable. Other parts of the hulls can be standardised, and many of the fittings can also be standardised, not only for one ship, but for many, as experience in other countries has sufficiently shown.

Rationalisation of the Work.—What follows from standardisation of parts? It follows that “the parts can be manufactured in different places, and at different times.”

If one considers the building of the hull of a ship as a piece of production work, one sees that the work of producing the parts could be done both better and more cheaply; that the parts can only be erected after they are made, and if they were all made before erection started (to go to extremes) it would be possible, by using more equipment and more men, to complete the erection in much shorter time, and thus set the building berth free.

It has been shown, in this way, that it is possible from a particular berth to launch a 10,000-ton freight steamer hull every 28 days. The usual time at present is not less than 9 months.

Thus the parts can be made anywhere, say at or near the steelworks, under factory conditions—that is, under proper control—and delivered to the building berth as fast as desired. The berth could be equipped and organised for rapid erection of ships of a certain *range* of sizes. The speed of erection would fix the rate of delivery, and perhaps the rate of manufacture of the parts.

Thus can be applied to ship-building, once parts are standardised, nearly all the methods of production and management that are used in manufacturing motor-cars or electrical goods. Can anybody who has seen ship-building carried on, and who has watched the operation of a well-organised factory, doubt that the result would be that the ship would be built in a very much shorter time, and that both production costs and overhead expenses would be greatly reduced in this part of the work?

(c) **Building.**—The standardisation of dwelling houses should be completely barred, just as the standardisation of anything else that has artistic and æsthetic value is barred. Æsthetic considerations, in such cases, are of much greater importance

than cost, especially when, as in the case of houses, the saving in cost by standardisation of the house itself is so small.

And yet, the cost of building houses is a very important matter, and its reduction would bring such immense benefit to everybody that anything really promising should be considered.

There has been for hundreds of years, in the common building brick, the beginning of standardisation of parts of houses. Other parts have also been standardised—fire-grates, baths, windows, doors, and so on—but the principal parts are still not standardised to the extent that they can be made or cut to size in a factory and be sent to the site ready to be put in place and nailed, screwed, or joined in some other appropriate way. To cut and make on the site is more costly than in the factory, and material is wasted. Why, then, is it done? Because the exact dimensions of a room are never known until it is built and measured, and the joinery and plumbing must fit exactly.

The dimensions of bricks are standard and vary little. A two-brick wall is nominally 9" thick, but it may be $8\frac{7}{8}$ " or $9\frac{1}{8}$ ", because the thickness of the joint may vary. The joint has not been standardised, and because of the lack of this step, further progress in standardisation of parts has stopped. If one considers standardisation of the thickness of joints in brickwork as a practical problem, one sees that it is exceedingly difficult of solution, and might require changes of material or design, either of the joint or the brick, or call for a new conception altogether.

New conceptions are forthcoming. It has been suggested that houses should be built, monolithic in structure, of concrete; of larger units, also of concrete; of castings bolted together, with steelwork frames clothed with brickwork to fit, and finally, of panels or units much larger than bricks, factory-made of concrete or steel. These units are large enough to secure the accuracy of dimensions of the structure, and to make erection quick and cheap, but small enough to permit some freedom of design to the architect. In this way, houses can be purchased from stock designs or to order, and erected on prepared foundations, complete with all services, and ready for occupation in a few days. Many hundreds of houses have been built in this way, and are undergoing their test in service. But whether they are successful or not, it is by applying the

principles of standardisation and interchangeability to the parts and fittings, and by manufacturing instead of building, that the problem of adequate houses at low cost and in large numbers will ultimately be solved.

In other types of building, steel frames play an important part. The various members of the frames are cut to length and prepared for joining together in the shops, and the site joints are usually made with bolts, but sometimes with rivets. Some of the members are themselves of compound construction—that is, they are built up of several parts, which supplement one another, and riveted; or, latterly, sometimes welded together at the works; they are still of such dimensions, shape, and weight, that they can be conveyed to the site, and there be lifted and secured in place.

The methods of preparing the members of these structures, in the workshops, or “fabricating” them, are capable of much improvement in the light of recent work both in the way of processes and equipment and in the greater use of the principles of the New Management. In the first place, the sections themselves are not standard in the sense of being the best that can be designed and made economically for their purpose. Methods of manufacture that make it possible to produce better (more economical) sections have since been developed, but these methods would involve the scrapping of existing mills and building new ones at considerable cost. This capital expenditure is not considered to be justified by the demand for the newer sections, in the markets available.

The smaller sections are sheared to length, and the larger ones sawn. Originally the saws were slow-running, cold saws, but these were superseded by high-speed discs which rotated with a peripheral speed of 28,000–30,000 feet per minute. During the past twelve or fifteen years, the cold saw has been very much improved, and can now cut as quickly as a high-speed disc, operate much more quietly, and give a cleaner and more accurate cut. This improvement has been widely adopted.

The method of marking the position of the holes, both for shop and field joints, is to draw the member, and if necessary contiguous members, full size on the template loft floor. Wooden templates are made of these, with holes drilled in where they

are required in the member. These templates are placed over the member, secured with clamps, and the holes marked through with paint dabs or brushes, an operation resembling stencilling. These dabs are centre punched, and the member is ready for drilling. The drilling is done, one or at most two holes at a time, on single spindle radial drills, arranged in line about 8' to 10' apart. The efficiency of these drilling machines—that is, ratio of cutting time to shift time—can never be more than 20 per cent., and is more often 12–14 per cent. The modern method of doing this work is to drill the holes direct—that is, without marking the members—with multiple spindle drills, fitted with mechanical devices for moving the tables, on which the members lie, a predetermined amount. Thus a large number of holes can be drilled at once, and then the piece can be moved with perfect accuracy into position for the next batch of holes. The accuracy obtained makes assembly and erection a quick and easy operation, and avoids straining of members by forcing holes into alignment with drifts.

The transport of material through the shops at present is almost exclusively by overhead cranes, and as the path of the work is along the shops—that is, parallel to the principal travel of the crane—interference between cranes on the same gantry is frequent and unavoidable. Thus transport is slow due to the method of slinging, waiting for crane service, and interference between cranes, and therefore costly.

Perhaps the worst features of these shops from an organising point of view is the method of bringing material into the shop, and the length of time it stays there. The usual practice is to bring as much material into the shop as it will hold, and consequently there is fully ten times as much material in a shop that is reasonably busy as is being worked upon, and it remains in the shop ten times as long as it should. The reasoning behind this practice is that the presence of abundant work in the shop acts as an urge to the men; but it increases the amount of capital absorbed in stocks, and work in progress, it congests the shop and greatly reduces its capacity, and increases the cost of handling, which is a large proportion of the total cost of fabrication.

The work should be fed into the shop, already cut to length, a piece at a time, as the machine for the first process is ready for

it, rapidly carried through the few simple processes, and taken out again. No work should be in the shop for more than three days, and by far the greater part of it should pass through all the processes in less than a single shift; thus something approaching continuous manufacture is obtained.

This section of the building trade therefore requires standardisation, improvement of methods and processes, progress planning, balancing of processes and continuity of operation, and better arrangements for handling materials.

It may be thought that the development of electric welding will render this rationalisation unnecessary. For light structures, where design for welding enables weight to be saved and the amount of welding is relatively small, this process is a very valuable and economical one, and methods of inspection and testing will make it dependable. But for heavy building structures it is, and will remain for a considerable time, more costly than riveted joints, especially if the method of making the latter is modernised.

(d) **Agriculture.**—Agriculture has not, until a few years ago, been an industry at all, as industries have been spoken of in the preceding pages. It has been an arduous occupation by which a number of individual and isolated workers have sought to make a living for themselves and their families; the results of their efforts have always been precarious and doubtful, and rarely successful as success is counted in industry; and those engaged in it as wage-earners have been amongst the most poorly paid in the country.

Whatever may be the causes of this condition, nobody could ever think that it is because farmers, individually or collectively, are inferior in any respect to the remainder of the population. It is, therefore, at once evident that the explanation of these conditions must be sought elsewhere, and to this end some features of the industry may be examined.

Climate.—It is pardonable, if with the memory of crop failure through too much or too little rain, or lack of sunshine, and of crops ready for harvesting ruined by bad weather, the farmer himself should be tempted to blame the climate for his ill-success.

But is this really so? Is the climate such a bad one, and cannot some of its vagaries be provided against, by drainage

in some cases and by irrigation in others? Before concluding that the climate renders successful agriculture impossible let us look at some other features.

Capital.—Agriculture as a field for the investment of capital is not, and never has been, attractive; probably the only people who invested money in farming have been the farmers themselves, and they have taken their interest on the capital invested not as dividends or profits, but as wages hardly earned by themselves and their families. It follows almost inevitably that, generally, the individual units of the industry have been short of capital, and it is almost equally inevitable that this has had the effect of perpetuating the use of old plant and methods, and rendering progress both in the invention of better machinery, and in the adoption of new methods to overcome the disadvantages of climate, exceedingly difficult.

Distribution and Selling.—Up to recently, the industry has had no selling organisation, and each farmer has transported his produce to market and sold it himself. And herein probably lies the most powerful cause of the failure of the industry. To-day, selling organisations have been built up, or have grown up, for the distribution of particular products, but whether these operate in favour of the producer, or merely exploit him, is open to question.

Take one product in particular—milk. Of the retail price of milk, nearly two-thirds go to the distributor, and slightly over one-third to the producer. If an article of food of such universal and necessary consumption as milk costs nearly twice as much to distribute as to produce, it suggests that the distribution leaves much to be desired in the way of organisation and efficient execution. And both the farmer and the public suffer.

The sale and distribution of other farm products are also in the hands of people other than the farmers, and yet, after all, they are probably carried out more efficiently than the farmers themselves, disunited and inexperienced, could possibly do it.

Lack of Specialisation.—It is not uncommon to find the same farmer growing hay, cereals, and roots, cow-keeping, fattening beasts for beef, pasturing sheep, and breeding pigs and poultry. No doubt this is partially due to difficulties in selling products, and is one way of avoiding the difficulty, since small quantities

of varied products can be disposed of in a relatively small area. Moreover, to a certain extent, variation of product tends towards economy both of time and material. Unfortunately, these foodstuffs, produced in a necessarily haphazard and unscientific manner—for it is impossible for one farmer to possess full scientific knowledge for all these purposes—have to compete with overseas products that have been grown on specialised farms using the results of all the latest research.

Integration.—The above features may be summarised as follows :—

(1) The units of the industry, the separate farmers, are independent and isolated, and have not realised that the interests they have in common are greater than those that divide them.

(2) The industry suffers from a general shortage of capital, and much of the capital employed therein is insufficiently active.

(3) There is a lack of specialisation.

(4) The sale and distribution of farm products is in other hands. These activities may or may not be carried on economically, but in any case, they are not undertaken in the interests of the producers.

(5) The climate is unreliable.

(6) The accumulation and spreading of scientific knowledge and its practical application has been neglected in the past, and only during the past few years has it become at all systematic, extensive, widely disseminated and practically used.

Is there not, at least, in this brief and roughly accurate statement, an indication of what the remedy must be? The separate units must combine in their common interests, and must, by virtue of this combination, be able to control, or at least to deal on equal terms with, the distributing trades. If integration was begun from this point of view, it would be possible to arrange that each farmer had available for his use, when he needed it, and on equitable terms, important pieces of plant, machinery, and other appliances of the most modern types known, and these appliances would be more completely

used than it is possible to use them on a single farm. This would reduce costs of production, and at the same time reduce capital charges. Plans for rationalisation of the industry and specialisation of its units could be developed.

Countering the vagaries of the climate is a matter for engineers, and an integrated agricultural industry could afford to employ engineers.

A united industry would know how to extend the knowledge of "scientific" farming, and quicken its dissemination.

It will be much less difficult to bring about this integration and combination to-day, than it would have been say twenty years ago; moreover, the means are available in a much higher degree. The people and the Government are alive to the necessity from the point of view of the national welfare, to establish agricultural industry on a stable and self-supporting basis, and the movement, once started, would be backed wholeheartedly by the public press, with the agricultural journals and the broadcasting service in strong support. These institutions could be relied upon for much more than propaganda. There must be, by now, many farmers who have been trained at an agricultural college, and many of these men and women are subscribers to and members of the Royal Agricultural Society; this Society, or an offshoot from it, might sponsor the whole movement.

(e) **Other Fields.**—It can be shown that given good leadership, some or all of the other principles of modern management, standardisation, continuous production, work and time studies, progress planning and inspection are applicable to all branches of industry without exception, and will bring improved quality and lowered cost of product. Wage costs can be lowered whilst wages are raised; more can be produced and with less effort, and greater safety be obtained because control is more complete.

The cotton trade, for example, suffers severely from Eastern competition, and this is said to be because in Eastern countries the workers are satisfied with wages that would be unthinkable here. Management and production research would certainly help to redress this disparity in wages, even if it were not a complete solution of the difficulty. It would find a way of making the superior qualities of British labour more effective. By the elimination of waste of time, effort, and material at

every stage, it would reduce the cost of production. The total cost of conversion from raw cotton to finished cloth would be analysed, and it would be shown what part the many changes of hands that take place plays in determining the final figure, and how much could be saved if transport from factory to warehouse, and from warehouse to factory, or even from factory to factory, were reduced; in other words, the analysis would show what would be the effect of "integrating" the manufacture, as steel-making and manipulation is integrated, and at the same time whether the present organisation of the cotton industry is satisfactory or not.

In the same way, it could help the coal industry. It could so reduce the cost of coal-getting as to make it possible to elaborate precautions against accidents to the point of elimination, and withal to improve conditions under which miners work.

In the pottery and wood-working industries there are the beginnings, but only the beginnings, of standardisation. Extension of this principle would, in itself, reduce the cost of production, and would enable other measures to be taken with the same object. Incidentally, the improvement of management in these industries would assist the building and other trades.

Nor is the applicability of the principles of management by any means limited to manufacturing industry; for there are hardly any fields of human activity in which they are not beneficial. It is to be expected, from what has been said, that they can be of service in Government and Municipal enterprises, but they can also be beneficially applied to the ordinary activities of these bodies. It is sufficiently evident that their value in large departmental stores and other extensive distributive undertakings has been discovered, but they can also help in the much wider field of small retail undertakings, and thus not only help these to maintain their position and continue the service they render, but also to reduce the general cost of distribution, which at present seems so heavy.

Similarly, there are examples of the value of these principles in public housekeeping, such as hotels, restaurants, and hospitals, and a much more widespread application in these fields is needed. But why not in private housekeeping?

Here is scope for improvement that may affect every man, woman, and child in the country, the women directly, and the men and children indirectly. In the early days of Scientific Management, Christine Frederick, a pupil of F. W. Taylor, showed what improvement could be made in housekeeping by the use of more scientific methods, and the ideas have been further developed by others.

A further example may show how one of these principles applied to a single branch of an industry, and apparently confined to that, can ultimately influence almost every point of the life of a nation. The example referred to is the standardisation of the size of paper sheets as it has been carried out in Germany. For this purpose it will suffice to say that the basis of this standardisation, worked out in logical sequence from the unit area of the metric system of measurement, has proved in application of very widespread effect and benefit. That this can be so will be realised by any one who has organised a filing system, a library or a bookbinding establishment; by any one who has folded a sheet of paper to go into an envelope, or paper money to fit a wallet, or slipped a wallet into his jacket pocket, or a photograph into a frame; by any one who has had to deal with a collection of drawings, with the arranging of figures in printed books, or the development of printed forms, such as bank cheques. Any one who has done any of these things (and who has not?) must agree that such a standardisation is very convenient; and, in addition, of considerable advantage to paper and paper-machine makers, and retail stationers. Moreover, allowing one's imagination to wander unchecked for a little, the utility of this standardisation of plane area sizes can be greatly increased by building up on the same principle the standardisation of cubic spaces, important in all matters of packing, storage, and transport. Hundreds of details of daily life are simplified, and losses diminished by standardisation. At any rate, that is the experience in Germany, where this standardisation has been carried out.

It often happens that changes in a relatively small field are found to have far-reaching reactions.

An improvement in industrial management is a change, the final effect of which nobody can predict. Most of the improvement already effected is the result of, or at least is accompanied by, sympathetic and friendly consideration of the point of view of the workers, which has, in turn, produced amongst workers a friendly and sympathetic understanding of the difficulties of managers, and so has brought about a sense of shared responsibility.

Is it too much to hope that this spirit of friendliness and co-operation—fostered, if you like, as a policy of good management—will spread to all industries; will become a habit, and gradually permeate all human relations, and thus help to bring ease to a troubled world?

BIBLIOGRAPHY

WE are privileged by the authors to suggest certain titles of the most advanced and practical books which handle in detail those subjects allied to the authors' text, the fuller discussion of which would have made this book too large.

Reverting to the list of Contents : Chapter I, *Factors of Economics*, possibly Professor Pigou's "Economics in Practice" (6342), from its avoidance of unnecessary long words and its constructive thought, would provide both authoritative and even humorous reading, Hobson's "Worth and Wealth" (6541) is also stimulating.

Chapter II, *Organisation*, suggests two complementary books, the "General Management section of the Handbook of Business Administration" (0115) and Fayol's "Industrial and General Administration" (0226). On production problems this text is probably sufficient, except for "The Cost and Production Handbook" (1843), which is an invaluable reference book for detailed factory and storekeeping problems. Larrabee's "How to Package for Profit" (2747) adds useful suggestions on the commercial sides of packing. Professor Dickenson's "Compensating Industrial Effort" (1090) is most valuable on wages. MacDonald's "Office Management" (0423) takes the typing and filing sections to their logical conclusion in efficient management. On Committees, Urwick's "Committees in Organisation" (0251) is short and authoritative.

Chapter III, *Work and Time Studies*. We regard this chapter as being as authoritative as anything yet written.

Chapter IV, *Some Important Features of Modern Production*. Lichtner's "Planned Control in Manufacturing" (1846) will round off any ambiguities which may occur to the reader.

Chapter V, *Standardisation and Inspection*. Reference is suggested to the publications of the British Standards Institution, especially in so far as technical standardisation, also treated in Chapter IV, 3, is concerned. The connection

between standardisation and inspection and the more general aspect of the former, as given in this chapter, are as far as we know, not yet treated in English literature in this manner.

Chapter VI, Simpson's "Industrial Accountancy" (4036) and Prior Sinclair's "Budgeting" (4166) are the two best books. Dr. D. J. Garden's "Flexible Budgeting and Control" (4169) reviews British practice.

Finally we must suggest Viteles two books "The Science of Work" (1553) for the man who does not like long words, and "Industrial Psychology" (1541) for those who have the language of psychology.

There are literally thousands of books published on these and kindred subjects, and we have selected fifteen only, realising that the reader already has expert knowledge on some of the subjects but would like to read up on the others, within the limits of having but a small amount of time to spare. The numbers quoted against each title are those of the book in the Management Library catalogues and this number alone is sufficient for members to call for, when wishing to borrow.

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